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Characteristics of alternative keyboard acquisition, setup, use, and benefits : a survey study

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CHARACTERISTICS OF ALTERNATIVE KEYBOARD ACQUISITION, SETUP, USE, AND BENEFITS: A SURVEY STUDY

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ABSTRACT

CHARACTERISTICS OF ALTERNATIVE KEYBOARD ACQUISITION, SETUP, USE, AND BENEFITS: A SURVEY STUDY

by Kenneth Scott Wright

This thesis describes the results of an alternative keyboard user survey. Two-hundred and twenty participants responded to the questionnaire. They were from business, government, and educational settings and used a wide variety of commercially available alternative keyboards. The questionnaire covers why alternative keyboards are acquired, setup and use patterns, benefits, and recommendations for improvement. Survey responses indicate that people primarily acquire alternative keyboards to help recover from injuries and to avoid potential injuries. Users report that alternative keyboard split and sculpted key layouts result in improved keying posture and comfort, reduced pain, and in many cases the ability to continue in their selected careers. This insight into why and how new keyboard designs are being used provides information needed to focus user education, research and design efforts in the field.

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INTRODUCTION

The use of computers has exploded in the last decade. Where there were 13 million computers in use in 1980, by 1990 there were 40 million. That number continues to increase (Gerard, Jones, Smith, Thomas, & Wang, 1994). What was an expensive research tool can now be found from elementary school classrooms to corporate executive offices. Computers are now standard office equipment and many service-oriented industries such as telecommunications, finance, travel, general business and government rely heavily upon them (Lyon, 1992).

A new problem has emerged with this increase in keyboard use. Zip, Haider, Halpern, and Rohmert (1983), in their review of field studies, report that keyboard operators (both typists and computer users) have more musculoskeletal problems and complaints than do individuals in non-keyboarding office jobs. The increased repetitive motions and awkward postures attributed to computer keyboards have resulted in an increase in cumulative trauma disorders (CTDs) that are generally considered to be the most costly and severe disorders occurring in the computer workplace (Lyon, 1992). Lawsuits for arm, wrist, and hand injuries have been filed against keyboard manufacturers (Feder, 1992). The authors of these suits contend that keyboarding equipment is defectively designed and manufacturers fail to provide adequate warnings about proper use to avoid injury. This rapid increase of computer use and its related keyboard injuries have lead to a variety of commercially available alternative keyboard designs.

Keyboard Design History

Reviewing the history and weaknesses of the standard keyboard's design will assist in better understanding the potential benefits in current, evolving keyboard designs. The primary method of entering information into the computer is through the keyboard. The keyboard's basic design of flat, linear rows of keys dates back to Christopher L. Sholes' design patented in 1868, commonly referred to as the "QWERTY" keyboard (after the top left-hand row of alphabetic keys). It is commonly believed that the major design problem for early keyboards was the interlocking of mechanical key arms during typing. Early typists used a hunt-and-peck method, employing one or two fingers from each hand. This typing method developed into an all-finger method that was used by most typing schools by 1900 (Cooper, 1983) and is still in use today. Most modern typewriters and computer keyboards still use Sholes' basic "QWERTY" keyboard layout despite the advent of electronic keying mechanisms, which eliminate the interlocking problem. As serious CTDs have been attributed to standard keyboard use, it is useful to look at the causes of these injuries to understand the impetus of today's alternative keyboards.

Postural Problems and Injuries Attributed to Keyboard Design

As early as1926, Klockenberg described how the keyboard layout required the typist to assume body postures that were unnatural, uncomfortable and fatiguing (Kroemer, 1972; Bailey, 1982). For example, standard keyboard design forces operators to place their hands in a flat, palm down position called forearm pronation. The compact, linear key arrangement also causes some typists to place their wrist in a position that is skewed

towards the little fingers, called ulnar deviation (Kroemer, 1972; Nakaseko, Grandjean, Hunting, & Gierer, 1985). These awkward postures, holding the hand and arm joints in non-neutral positions, results in static muscle loading, increased muscular energy expenditure, reduced muscular waste removal, and eventual discomfort or injury. Figure 1 shows several awkward postures attributed to increasing CTD risk and defines important terms that appear in this paper.

Duncan and Ferguson (1974) made detailed observations of operating postures of teleprinter operators complaining of injury symptoms. From observations of operators with and without symptoms, non-neutral operating postures were identified as important predictors of injury symptoms. Their findings establish a relationship between symptoms incurred in teleprinter operations and awkward operating postures. The authors concluded that keyboard design and work height lead to awkward postures. Repeated exposure to awkward postures leads to injury symptoms in some operators. Ferguson and Duncan (1974) also noted that the keying load on each finger is poorly distributed, with QWERTY keyboards causing the weaker ring and little fingers to be overworked.

Collectively these studies suggest that the standard keyboard design contributes to the development of CTDs. Not surprisingly, several researchers have examined alternative keyboard designs to alleviate these weaknesses of the original keyboard design.

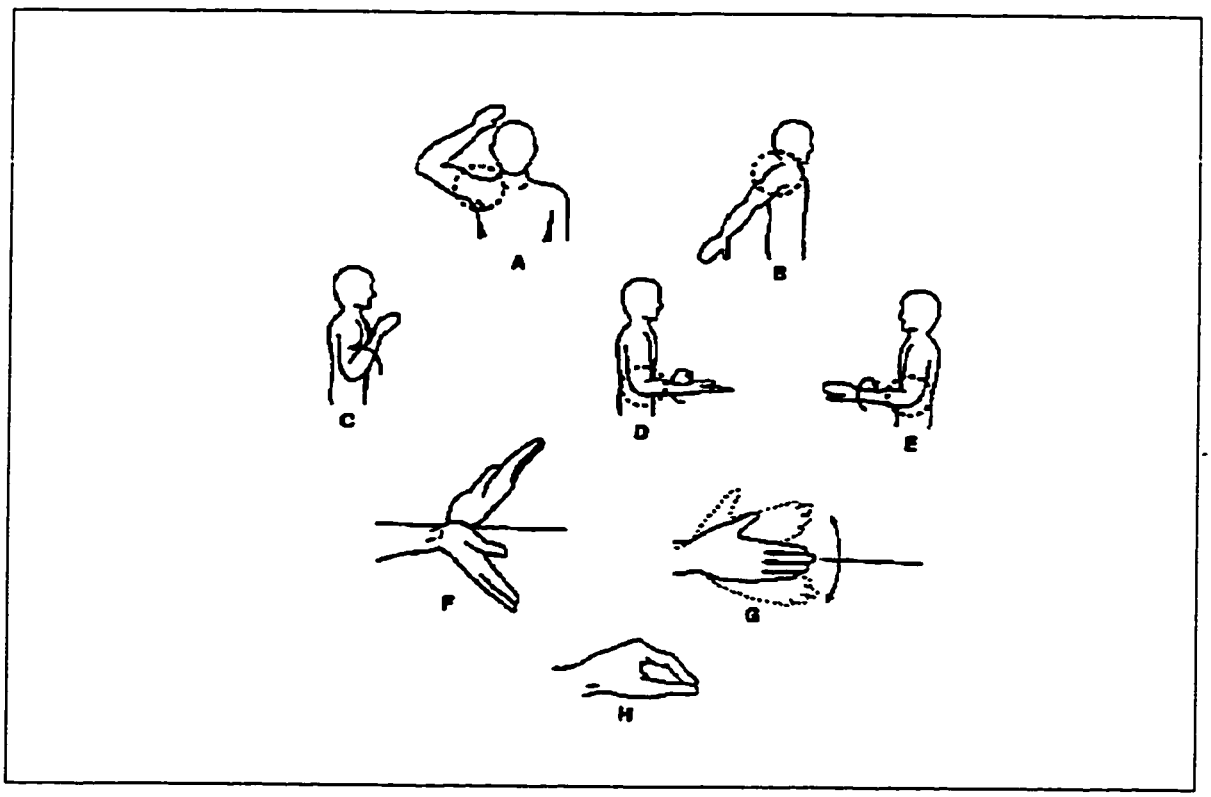


Figure 1. Postural risk factors for cumulative trauma disorders (CTD). Related terms and descriptions are provided below:

A - Shoulder Abduction	Raising the upper-arm away from the body
B - Shoulder Extension	Moving the upper-arm backwards, behind the body
C - Elbow Flexion	Bending the forearm to the upper arm
D - Forearm Supination	Rotating the forearm outwards to a palm-up position
E - Forearm Pronation	Rotating the forearm inwards to a palm-down position
F - Wrist Flexion	Bending the wrist downwards, towards the palm of the hand
Wrist Extension	Bending the wrist upwards, towards the back of the hand
G - Ulnar Deviation	Bending the wrist sidewards towards the little finger
Radial Deviation	Bending the wrist sidewards towards the thumb
H - Pinch Grip	Holding objects by pinching them with the fingertips

Efforts to Improve Keyboard Design

Several different design approaches have been used to improve Sholes' QWERTY keyboard to improve user productivity and reduce CTD injury risks. These design variations include the Dvorak, chording, and split keyboards

Dvorak Keyboard Layout

In 1936, August Dvorak, a professor of statistics at University of Washington, proposed rearranging the keyboard's alphabetic keys in a layout that is more equitable to the fingers. His design improved efficiency by placing common letters on the home row and also making the stronger fingers do most of the work.

The Dvorak layout has been accepted by the American National Standards Institute (ANSI) and has its advocates. However, it has not received wide-spread acceptance because of the many typists trained to use QWERTY keyboards and the costs related to switching over to a new keyboard design (Cushman & Rosenburg, 1991; Pulat, 1992).

Chording Keyboards

The chording keyboard is a second, proposed alternative to the standard keyboard. Chording keyboards are smaller and have fewer keys, typically one for each finger and possibly the thumbs. Instead of the usual sequential, one-at-a-time key presses, chording requires simultaneous key presses for each character typed, similar to playing a musical chord on a piano (Cushman & Rosenburg, 1991). The primary advantage of the chording keyboard is that it requires far fewer keys than a conventional keyboard. For example, with five keys there are 31 chord combinations that may represent letters, numbers, words,

commands, or other strings (Noyes, 1983). With fewer keys, finger travel is minimized because the fingers always remain on the same keys. In addition, the user is free to place the keyboard wherever it is convenient and may avoid the unnatural keying posture associated with a conventional keyboard (Cushman & Rosenburg, 1991). The most significant disadvantage of the chording keyboard is that it cannot be used by an untrained person. At least 15 hours of training and practice are necessary to learn the chord patterns that represent individual letters and numbers (Lueder, 1985). A second disadvantage of the chording keyboard is that data entry rates (characters per unit of time) are actually slower than data entry rates for conventional keyboards (Noyes, 1983). Due to the increased learning time and slower performance, chording keyboards have not become commercially viable except for specialized applications.

Split Keyboards

Most of the research and design efforts have focused on re-shaping the standard keyboard, or making it more adjustable, while keeping its basic shape and well-learned QWERTY key arrangement. This direction of study assists in the transfer of learning from what typists are currently using to new designs that provide for improved hand and arm postures during use.

In 1926 Klockenberg suggested a number of improvements to the keyboard layout in a book dealing with the design and operation of the typewriter. One of his ideas was to separate and incline the left and right hand keyboard sections to alleviate tension in the typist's shoulders and arms (Bailey, 1982).

Kroemer's (1972) research followed Klockenberg's ideas and provided support for several design concepts: (1) Keys should be arranged in a "hand-configured" grouping to simplify finger motion patterns, (2) Keyboard sections for each hand should be physically separated to facilitate finger positioning, and (3) Laterally declined keyboard sections for each hand would reduce postural muscular strain.

Zip et al. (1983) also recommended a split keyboard that allocated a key field to each hand for long-term typing tasks. These researchers propose splitting the keyboard in half, at the middle, and angling the alphanumeric key fields outward from the center (horizontal split or opening angle). This arrangement allows the typist to angle the keyboard sections so that awkward wrist postures attributed to injuries may be reduced. Another version of this concept is to separate the two keyboard sections, without angling, so that each key field is located in front of the shoulders. These split configurations (angled or separated) permit users to operate the keys with neutral, or straight, wrists that reduce or eliminate one of keyboarding's awkward postures, ulnar deviation of the wrists.

Forearm pronation is another awkward posture related to the use of flat, horizontal keyboards. Some alternative keyboard designs also tilt the right and left keyboard halves upwards in the middle (lateral angle or tenting), similar to an A-frame. As the left- and right-hand key segments are no longer flat, the "palm down" position related to forearm pronation is reduced.

The intent of these modifications (see Figure 2) is to reduce the awkward hand, wrist, and arm postures that are common injury risk factors (Thompson, Thomas, Cone,

Daponte, & Markison, 1990). An increasing number of studies are being performed to identify the benefits of these designs for both experimental models and actual products.

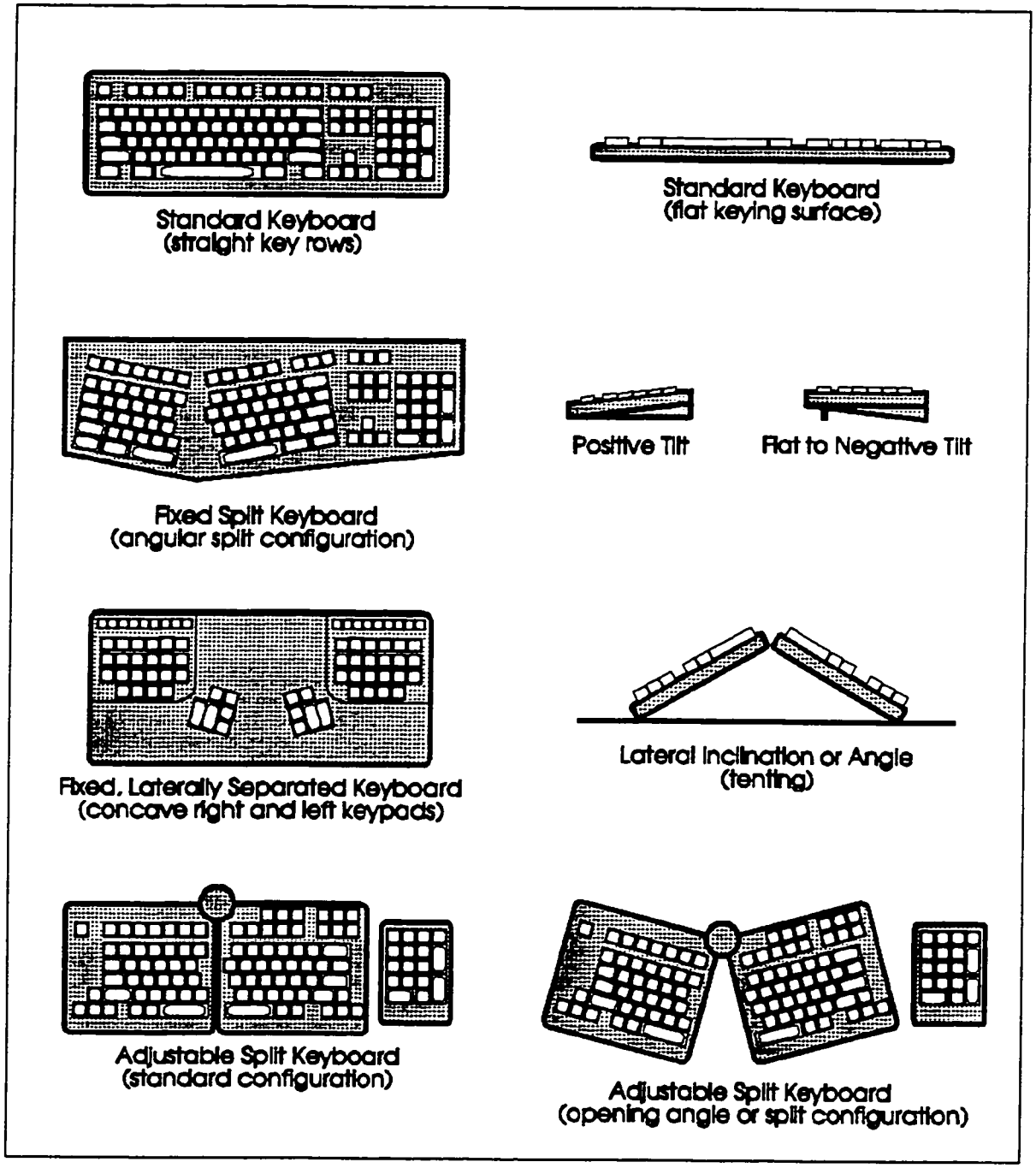


Figure 2. Common alternative keyboard configurations

Split Keyboard Research

Laboratory research has used both adjustable fixtures and commercially available keyboards in selected configurations to determine optimal design parameters. Table 1 shows a summary of the opening and lateral angles that have been examined, and their recommended values.

Table 1

Summary of Tested and Recommended Keyboard Configurations

	Tested Angles		Recommended Angles	
Study	Horizontal	Vertical	Horizontal	Vertical
Creamer & Trumbo (1960)	N/A	0, 22, 44, 66,	N/A	44, 66
Kroemer (1972) Exp #1	N/A	N/A	N/A	40
Kroemer (1972) Exp #2	30	0, 30, 60, 90	N/A	N/A
Kroemer (1972) Exp #3	50	45	N/A	N/A
Zip, et al. (1983) Exp #2	N/A	N/A	0-15	0-60
Zip, et al. (1983) Exp #3	13, 26	10, 20, 30	10-20	10-20
Nakaseko, et al. (1985)	0, 25, 35	0, 10	25	10
Ilg (1987)	N/A	N/A	N/A	8
Thompson, et al. (1990)	0, 15, 30	0, 30, 60	18	30-60

Various methods have been used to quantify the benefits of split keyboards. These methods include productivity, preference, biomechanical, and physiological measures as are shown in Table 2.

Table 2

Summary of Measures Used for Keyboard Laboratory Research

Term	Definition	
Productivity	Typing speed	- typed characters per set time period
		- time to type set number of characters
	Number of errors	
	Session duration	
	Reason for ending session	
Preference	Comfort level of keyboard use	
	Preferred keyboard type or configuration	
	Ease of use	
Biomechanical	Torso and upper extremity (hands, arms, shoulders) posture	
	Fingertip impact force	
	Tendon strain	
Physiological	Electromyographic (EMG) measurements	
	Heart rate	
	Nerve conduction velocity	
	Vibrometry,	
	Hand strength	
	Finger digit temperature	
	Hand volume	
	Reported pain	
	Level of relaxation	

Horizontal Opening Angle (Keyboard Split)

A variety of experiments have been performed to explore ranges of keyboard split angles. Zip, Haider, Halpern, and Rohmert (1983) studied the effects of different keyboard configurations through the use of EMG measurements. A thin bar was fixed at various angles between two stands to simulate a keyboard's home row. The angles of simulated key field rotation were 13 and 26 degrees. By splitting the key fields, the strain on hand, neck, shoulder, and arm muscles were reduced. They concluded that the optimal range for ulnar abduction was 0 to 15 degrees. These were outside the normal positions observed for typewriting at a workstation, which were observed at 20 to 25 degrees for ulnar abduction. They concluded that a split keyboard should have two symmetrical key fields, each rotated in the horizontal plane at an angle of 10 to 20 degrees.

Kroemer (1972) used 30 and 50 degree split angle in his experiments. When comparing a 50 degree split angle, to a standard keyboard, he found no significant differences between the tapping rate or heart rate. There was, however, a 7.7% error rate at the K-keyboard versus a 12.7 error rate at the standard keyboard. The participants expressed reasons for ending the session appeared to favor the K-keyboard due to less comments related to aches and pains as compared to the standard keyboard.

Nakaseko, Grandjean, Hunting, and Gierer (1985) used opening angles of 0, 25, and 35 degrees. They concluded that the subjects gave a clear preference for the split keyboard with an opening angle of 25 degrees.

Thompson, Thomas, Cone, Daponte, and Markison (1990) used a variable geometry keyboard with opening angles of 0, 15, and 30 degrees. They reported minimized objective EMG activity and subjective discomfort with split keyboards when the wrists were in a neutral position. The best opening angle was concluded to be 18 degrees.

Sommerich (1994) measured carpal tunnel pressure (CTP) using a commercial keyboard in both standard and split conditions. She found that splitting the keyboard eases ulnar deviation and also results in less pressure in the wrist's carpal tunnel. It is important to note that poor wrist posture not only affects muscle activity, but also CTP, which may contribute to keyboard-related CTD injuries (Weiss, Bloom, Gordon, & Rempel, 1992; Honan, Serina, Tal, & Rempel, 1995).

These studies show a benefit of splitting keyboard segments and angling them to reduce ulnar deviation. Tested opening angles varied from 0 to 35 degrees with recommended angles varying from 10 to 25 degrees. The amount of adjustment would likely depend upon the body width of the user. Wider shoulders and torsos would result in the need for increased keyboard split angle to maintain a neutral wrist posture.

Sculpted Keyboard

A variation on the split, angled keyboard design is where the keys are separated apart and set in a sculpted or "dished-out" depression on each side of the keyboard. These keyboards use the physical separation of the key segments to reduce wrist deviation, instead of angling them.

Gerard, Jones, Smith, Thomas, and Wang (1994) used EMG in evaluation of a sculpted keyboard called the Kinesis ergonomic keyboard. They determined that the resting posture of the hands on the Kinesis keyboard required significantly less activity to maintain as compared to a standard keyboard. Reduced muscular activity was also measured for typing, which may be attributable to the Kinesis' unique key arrangement.

Vertical Inclination (Keyboard Tenting)

Reduction of forearm pronation during typing has been studied by vertically angling the keyboard's segments. Kroemer (1972) had his participants hold rods in their hands and rotate their forearms until they were at their most comfortable position. Participants performed this process with their arms hanging vertically or elevated laterally by 15, 45 or 90 degrees. Most participants preferred a mid-range (40 degree) forearm pronation angle. A similar study by Zip, et al. (1983) concluded that the optimal range for pronation was 0 to 60 degrees. Typewriting at a workstation was observed as requiring 90 degrees of forearm pronation.

Several studies used wide ranges of vertical inclination angles. Creamer and Trumbo (1960) tested inclination angles of 0, 22, 44, 66, and 88 degrees using a fixture hinged in the middle that had the typewriter's eight home row keys. The rate of tapping was found to be greatest at the positions intermediate between horizontal and vertical. All participants reported that the 0-degree setting was the most fatiguing, and split their preferences between the 44 and 66 degree lateral angle settings.

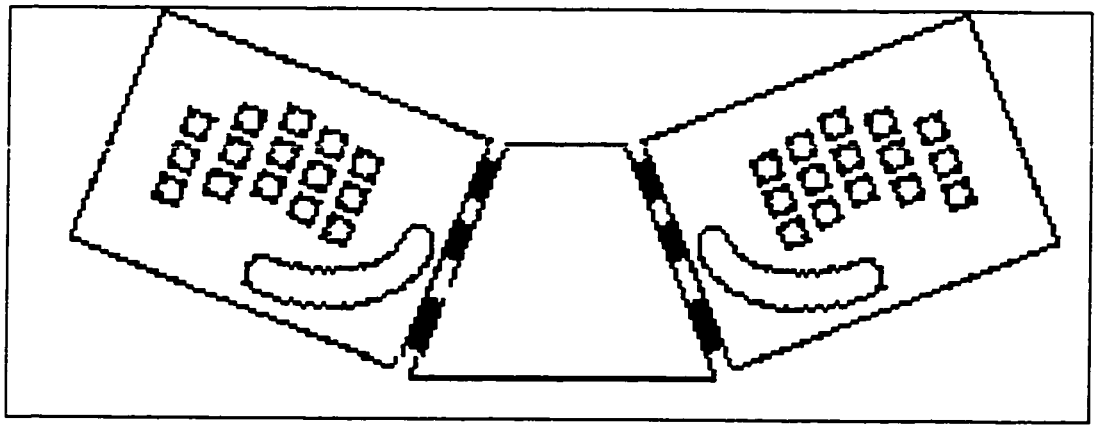


Figure 3. Drawing of K-Keyboard

In one of his experiments, Kroemer (1972) used an experimental split keyboard (see Figure 3) with lateral declinations of 0, 30, 60, and 90 degrees. No significant differences existed for either typing speed or errors when using the different configurations. The only marked difference on the preference data was that 17 of 25 participants preferred the 60-degree declination to the horizontal configuration. Thompson, et al. (1990) also used a variable geometry keyboard with lateral inclinations at 0, 30, and 60 degrees from the horizontal. The authors reported minimized objective EMG activity and subjective discomfort. The best configuration was concluded to be with a 30- to 60-degree lateral angle.

Some researches limited the vertical keyboard angling used in their experimental conditions that resulted in recommendations more conservative than those above. Zip, et al. (1983) used a thin bar was fixed at various angles between two stands to simulate a keyboard's home row. The angles of the simulated split keyboard's lateral inclination were 10, 20, and 30 degrees. They concluded that a split keyboard should have laterally inclined

key fields from 10 to 20 degrees. Nakaseko, et al. (1985) used an adjustable, split keyboard to study lateral inclinations of 0 and 10 degrees. They concluded that the subjects gave a clear preference for the split keyboard with a lateral angle of 10 degrees. Ilg (1987) performed extensive laboratory evaluations of experimental keyboards and concluded an optimal lateral inclination parameter of 8 degrees.

These studies recommend vertical inclination of keyboard segments to reduce forearm pronation. Tested tenting angles varied from 0 to 90 degrees with recommended angles varying from 8 to 60 degrees. Mid-range vertical angling of 30 to 60 degrees were recommended by researchers using the more acutely angled configurations. Benefits of lesser inclinations of 8 to 20 degrees were also noted by studies limiting the angle used for keyboard vertical inclination. The more extreme angles might prove more difficult for people who do not touch-type and need to look at the keyboard while typing.

Summary

The above research has shown that changes in keyboard design have resulted in increased comfort, improved postures, reduced muscle activity and lower carpal tunnel pressure in laboratory settings. Users' speed and accuracy typically seem to suffer through a learning curve period although Hobday (1988) reported improvement in performance and a substantial reduction in error and fatigue.

New laboratories are being established that use multivariate measures to evaluate and optimize alternative keyboards designs. Smutz, Serina and Rempel (1994) report on the UC San Francisco/Berkeley ergonomics lab using evaluation measures of fingertip impact

force, wrist position, productivity, comfort and ease of use. Other research has begun to insert alternative keyboards into real work situations for limited periods of time (Morelli, Johnson, Reddell, & Lau, 1995).

A weakness of many of these studies is the short exposure that subjects have to the alternative keyboard designs. Subjects have typically used the alternative keyboards for periods of time ranging from a few hours to a few days. Such short accommodation periods frequently result in standard keyboards rating higher for speed and accuracy while alternative keyboards are rated better for muscle load and comfort (Honan, et al., 1995; Smith & Cronin, 1993; Brigham & Clark, 1986). Longer term impacts on worker health and productivity using alternative keyboards still need to be studied. The present study takes this step by going to the users of commercially available alternative keyboards to determine what design characteristics lead to their acquisition and how setup, use, and benefits match with those reported from laboratory research.

The Present Study

Several sources of information were used to identify the different alternative keyboards that are commercially available and collect background data on them to develop specific survey questions. A literature search was made of keyboard design and adjustability issues, which have largely been discussed earlier. Keyboard advertising and user instructions were obtained from distributors and manufacturers to determine on what information the users have available to base their keyboard selection, setup and methods of use. Internet sources were searched to collect both commercial information and user

comments and experiences regarding their alternative keyboard use. With this background information, a questionnaire was developed to query alternative keyboard users about the acquisition of specific alternative keyboards, their setup and use patterns, perceived benefits, satisfaction, and recommendations for improvement.

Alternative keyboards selected for this survey study vary from those very similar to the standard QWERTY design with only a horizontal split in the middle (e.g., generic split keyboards), to ones that have integrated palm rests and finger wells with multiple switches for each finger (e.g., DataHand). Table 3 provides a quick-reference for each of the commercially alternative keyboard designs and their category classifications being used for the purpose of this study (see Appendix I for additional information).

Table 3

Selected Alternative Keyboard Design Configurations and Adjustability

Categories and Keyboard Names	Horizontal Opening Angle	Vertical Inclination Angle	Adjustable
Fixed Split			
Adesso	Yes	Yes	No
Generic Split	Yes	No	No
Microsoft Natural	Yes	Yes	No
MiniErgo	Yes	Yes	No
MyKey	Yes	Yes	No
Sculpted			
Kinesis	Yes	No	No
Maltron	Yes	No	No
Adjustable Split			
Apple Adjustable	Yes	No	Yes
Comfort	Yes	Yes	Yes
ErgoLogic / FlexPro	Yes	Yes	Yes (Linked)
LexMark Select-Ease	Yes	Yes	Yes
Other			
DataHand	Yes	No	Yes

Alternative keyboards were grouped into several categories for the purposes of this study. Fixed Split Keyboards maintain the standard key-spacing and size while introducing an opening angle and some vertical angling of the keys (except for the Generic Split). The MiniErgo also has a detachable numeric keypad. Sculpted Keyboards separate the left and right hand key fields at a fixed distance, without angling, and arrange the keys in sculpted, dished-out depressions. Adjustable Split Keyboards can vary their horizontal and vertical split angles, with the exception of the Apple Adjustable which remains flat. These keyboards have detached numeric keypads except for the ErgoLogic/FlexPro keyboard whose angling mechanism also does not allow independent adjustments in the horizontal and vertical planes. The DataHand is largely in a class of its own, being a hybrid somewhere between a standard and chording keyboard.

Fixed Split Keyboards are more readily available on the commercial market while the Sculpted and Adjustable Split Keyboards are more drastic in their design changes and thus have a more selective market due to their higher cost.

Despite the variety of laboratory methods used to evaluate these keyboard configurations, no published study has examined how these keyboards are actually being used by those who purchase them. Therefore, the purpose of the present study is to query actual users of alternative keyboards about: (1) how they selected their keyboard from among the different alternative keyboard designs commercially available, (2) how they setup and use those keyboards, and (3) the benefits they experience from using the different alternative keyboard designs. Those perceived benefits will then be compared to

those predicted in the literature. This moves alternative keyboard research from the lab and queries real users in business, government and educational settings who have extended durations of exposure to these alternative designs. A primary issue is whether recommended keyboard configurations from literature are of benefit when applied to real-world products.

Chapter 2

METHOD

Survey Questionnaire

A user survey was developed (see Appendix II) that focuses on many of the issues identified in the literature search, manufacturer information, and Internet searches. The questionnaire consisted of five sections focusing on user information, alternative keyboard information, setup and use of alternative keyboard, benefits achieved form alternative keyboard, and recommendations for changes.

The introduction to the survey stated that the purpose of the study is to query users of alternative keyboards about the key issues of acquisition, setup, use, benefits, satisfaction, and recommendations for improvement. Participants were told that information provided will help improve instructional, research and design efforts in the field. Assurances of anonymity were provided as only summarized trends and anonymous comments are reported.

User Information (questions 1-10)

Each participant was asked for various pieces of background information to help identify potential correlations between the alternative keyboard selected and certain personal, professional, and computer-use related variables. As the questionnaire was distributed both locally and internationally (via the Internet), the state or country of participants is determined to track from where they are responding.

Personal characteristics such as age, height, weight, gender and hand size provide an initial mental model of the participant. Questions on occupation and computer use were asked to determine the type and duration of computer use that is being performed and their potential relationship to keyboard preference. For example, those who need to look frequently at the keyboard may prefer a more level keyboard as compared to someone that is a skilled touch typist. Individuals who use a mouse a lot might select a keyboard with a separate ten-key pad so that the mouse may be placed closer to them during use. It would also be consistent to expect that those with a lot of computer use or discomfort from computer work would be more likely to acquire an alternative keyboard as compared to those people who have no pain. Thus, information about users and the type of computer work they perform may provide part of the reason why alternative keyboards were acquired.

Alternative Keyboard Information (questions 11-22)

In this section of the questionnaire, participants were asked why they bought an alternative keyboard. The specific keyboard purchased, duration of use and price is queried along with information on other keyboards that may have been considered and rejected. The criteria used in selecting a keyboard provides information on what features are important to the user to address discomforts or to more effectively perform work requirements. Discomforts when using the previous and alternative keyboards may provide insight into user's perceived musculoskeletal relief from the alternative keyboard design.

There are a wide variety of reasons why individuals might purchase a keyboard with an alternative design. Due to the relatively high cost of these keyboards and their recent arrival on the marketplace, many individuals purchase these keyboards through workers compensation insurance when they experience injury symptoms in the workplace.

Setup and Use of Alternative Keyboard (questions 23-35)

In questions 23 through 35, participants were asked about setting up their keyboard. Questions included the time it takes to install and adjust the keyboard, what aids were available to ensure proper setup configuration, what adjustments were available, how easy they were to adjust and whether or not they change those adjustments.

Some concerns that have been voiced in the literature include the consistent use of wrist rests and the proper height of the keyboard support surface. As keyboards are part of a larger work system, these items were queried to determine if other workstation issues were also addressed with the purchase of an alternative keyboard. With information about the keyboard set up and use characteristics already acquired by the survey, it is time to determine what results were being obtained from alternative keyboard use.

Benefits Achieved from Alternative Keyboard (questions 36-46)

Participants were asked to rate their alternative keyboard against their previous keyboard using a seven-point scale running from much worse (1) to much better (7). These scales included issues similar to those in previous research covering biomechanical, physiological, productivity, and keyboard preference measures. The biomechanics of arm and hand posture are rated along with related physiological issues of aches and pains,

fatigue from use and keyboard comfort. Typing speed and accuracy were rated as the primary performance issues. Keyboard preference was measured for key positioning, feel of keys, learning to use and adjustability.

Recommendations for Changes (questions 47-49)

Realizing that no product is perfect, the user is asked to define the best and worst attributes about their keyboard. They were also asked their opinion on how the keyboard might be improved. These questions provided open-ended questions to close the survey and let the participants expand on issues not otherwise collected in the survey.

Survey Feedback

At the end of the survey, an opportunity was provided to receive a summary of the survey's results and also to identify themselves if they would be willing to participate in follow-up interviews or surveys. Many users of alternative keyboards, and those investigating such products, are constantly looking for information on them. This section provides a built-in incentive for users to complete the survey and provide accurate information. Those that are willing to participate further in the research of alternative keyboards become a valuable resource in follow-up interviews or surveys that may clarify vague responses or possibly provide for future research into the effectiveness of these alternative designs over time.

Survey Procedure

The survey started on February 15, 1996 and responses for this paper were taken until May 25, 1996. The questionnaire was provided to participants in either on-line (email or

Web formats) or paper form, as they requested. The survey was announced primarily through Listservers and Newgroups on the Internet that potentially have alternative keyboard users or medical, safety and ergonomics professionals who recommend them (see Table 4). As these groups typically do not take kindly to long postings, an abbreviated announcement of the survey and call for participants was posted several times during the course of the study allowing respondents to volunteer for the study.

Table 4

Listservers and Newsgroups Used for Announcement Distribution

Listservers:	
Alt-Keyboards	alt-keyboards@gu.uwa.edu.au
C+Health	c+health@iubvm.ucs.undiana.edu
ErgoWeb-List	ergoweb-list@ergoweb.mech.utah.edu
Humfac-L	humfac-l@uga.cc.uga.edu
RSI Network	crose@applelink.apple.com
RSI-East	rsi-east@sjuvm.stjohns.edu
RSI-UK	rsi-uk@tictac.demon.co.uk
Safety	safety@uvmvm.uvm.edu
Sorehand	sorehand@itssrv1.ucsf.edu
TechWriter-L	techwr-l@listserv.okstate.edu
Utest	utest@hubcap.clemson.edu
Newsgroups:	
comp.human-factors	
comp.periphs	
misc.health.injuries.rsi.misc	
misc.health.therapy.occupational	
sci.engr.safety	
sci.med.occupational	

A paper version announcing the survey study (see Figure 4) was also distributed to local organizational contacts, physical therapists, repetitive strain injury (RSI) support

groups, and other interested parties who were contacted to help identify, and distribute surveys to alternative keyboard users.

PARTICIPANTS SOUGHT FOR ALTERNATIVE KEYBOARD SURVEY STUDY

A survey study about alternative keyboard use is in progress as part of a Masters Thesis in Human Factors & Ergonomics at San Jose State University. The project is funded by Interface Analysis Associates and is advised by Dr. Anthony D. Andre. This survey builds upon laboratory research findings and queries actual users about their experiences with alternative keyboards, such as the Microsoft Natural, Kinesis, Lexmark, Comfort, DataHand, etc.. Key issues covered by the survey are why users acquire specific alternative keyboards, their setup and use patterns, perceived benefits, user satisfaction, and recommendations for improvement. Insight gained from this study will help improve instructional, research and design efforts in the field.

If you are currently using an alternative keyboard and want to participate, contact:

Scott Wright
2013 Princeton Ct,
Los Banos CA 93635
Work: (408) 742-3473
Home: (209) 826-8443
<wrightks@telis.org>

Dr. Anthony D. Andre
Interface Analysis Associates
1135 S. De Anza Blvd
San Jose, CA 95129
Fax: (408) 342-9059
<andre@interface-analysis.com>

The survey is available in paper and e-mail formats, and as a World Wide Web form at:
<http://www.interface-analysis.com/keyboard/survey. html>

Thank you very much for your interest.

Figure 4. Announcement of alternative keyboard survey

Use of the web site was encouraged in the announcement and questionnaire's introduction to ease the completion of the questionnaire and facilitate submission for the study. In the case of email responses, participants were able to respond to the questions and return the questionnaire directly back to the sender using the "Reply" function on their email software. A few participants opted to print out the survey and then Fax or mail it back for inclusion in the study. Those respondents using the web version of the survey

were able to select a "Submit" button on the form to place their answers into a response file that collected the web-sourced information. Participants using the paper version, or a printout of one of the on-line versions, either Faxed or mailed their responses back.

Survey Participants

Two-hundred twenty alternative keyboard users participated in this survey from across the United States and also internationally. Most participants (94%) responded through on-line means, which were evenly divided between email and web responses. The remaining six percent responded by Faxing or mailing in their questionnaires. As announcements of the surveys were primarily distributed electronically, and not mass mailings of the surveys, it is not possible to determine response rates from this survey study.

Chapter 3

RESULTS

Questionnaire responses were collected in a Microsoft Excel™ spreadsheet for data reduction and analysis. Results from the questionnaire's sections on user information, alternative keyboard information, setup and use of alternative keyboard, perceived benefits, and recommendations for changes, are provided below. Respondents were from a variety of occupations, with a heavier weighting to jobs in the computer industry (see Table 5).

Table 5

Occupations Responding to Questionnaire

Occupation	% Responses
Computer / Software Design	31%
Writer / Illustrator	12%
Administrative	8%
Consultant	8%
Safety / Ergo / Medical	8%
Secretary / Clerk / Assistant	7%
Other	7%
Student / Faculty	7%
Engineering / Technician	7%
Research	4%

Summary information provided is across all alternative keyboard types unless otherwise stated. The variety of alternative keyboards used by participants are shown in Table 6.

Table 6

Responses by Alternative Keyboard Used

Keyboard Name	Responses	Use Duration (Mean)
Adesso	12	0.3-24 months (4.4)
Apple Adjustable	16	1-36 months (19.0)
Comfort	8	1-29 months (16.1)
DataHand	7	0.3-48 months (19.2)
ErgoLogic / FlexPro	8	6-24 months (12.5)
Kinesis	21	0.3-36 months (10.8)
LexMark Select-Ease	24	1-24 months (7.9)
Maltron	4	1-36 months (14.3)
Microsoft Natural	109	0.3-24 months (8.9)
Other	11	N/A
TOTAL	220	0.3-48 months (10.2)

User Information

Summary of self-reported user attributes and computer use characteristics across all keyboard types are provided in Tables 7 and 8, respectively.

Table 7

Summary of User Attributes

User Attributes		No. Responses
Gender	male	128
	female	90
Hand Size	small	36
	medium	117
	large	65
		Range (Mean)
Age		18-64 years (36.6)
Height		54-78.5 inches (68.6)
Weight		100-400 pounds (173)

Table 8

Computer Use Characteristics

Use Characteristic	Mean
Daily Computer Use	6.3 hours
keyboard use	68%
numeric keypad use	4%
mouse use	25%

Typing Style	No. Responses
Hunt & Peck	1
Touch & Look	137
Touch Type	80

Alternative Keyboard Information

The reasons why users acquired their alternative keyboard are summated in Table 9.

Specific keyboard characteristics considered with those purchases are shown in Table 10.

Table 9

Why Alternative Keyboards Were Obtained

	All N-220	Adesso N=12	Apple N=16	Comfort N=8	DataHand N=7
Disability Accommodation	17%	0%	6%	38%	43%
Existing Injury/Pain	65%	58%	50%	75%	86%
Avoid Potential Injury	40%	67%	56%	13%	29%
Recommended/Provided	25%	8%	19%	25%	14%
Adjustable Design	23%	0%	69%	50%	0%
State-of-the-Art/Looked Cool	9%	0%	0%	13%	0%
No Particular Reason	1%	0%	0%	0%	0%

Table 9 (con't)

Why Alternative Keyboards Were Obtained

	ErgoLogic N=8	Kinesis N=21	Lexmark N=24	Maltron N=4	Microsoft N=109
Disability Accommodation	25%	19%	38%	0%	13%
Existing Injury/Pain	75%	95%	75%	100%	53%
Avoid Potential Injury	25%	29%	38%	25%	43%
Recommended/Provided	13%	29%	38%	25%	28%
Adjustable Design	75%	5%	67%	0%	9%
State-of-the-Art/Looked Cool	0%	10%	4%	0%	11%
No Particular Reason	0%	0%	0%	0%	2%

Table 10

How Alternative Keyboards Were Selected

	All N-220	Adesso N=12	Apple N=16	Comfort N=8	DataHand N=7
Cost	29%	50%	13%	13%	0%
Adjustability	30%	0%	81%	75%	29%
Split/Separated Keys	67%	75%	75%	75%	43%
Key Force/Feel	28%	8%	13%	13%	100%
Key Programmability	10%	0%	6%	13%	0%
Palm Resting Surface	30%	50%	25%	0%	29%
Recommended	18%	17%	6%	38%	29%

Table 10 (con't)

How Alternative Keyboards Were Selected

	ErgoLogic N=8	Kinesis N=21	Lexmark N=24	Maltron N=4	Microsoft N=109
Cost	38%	19%	21%	0%	34%
Adjustability	88%	0%	75%	0%	16%
Split/Separated Keys	63%	62%	92%	75%	61%
Key Force/Feel	38%	24%	29%	25%	28%
Key Programmability	13%	48%	0%	0%	6%
Palm Resting Surface	25%	10%	0%	0%	46%
Recommended	0%	38%	29%	75%	13%

Survey participants usually made the decision to acquire the specific keyboard purchased (81%), as opposed to having their company (10%) or medical/ergonomics professionals (5%) provide the alternative keyboard to use.

Across all keyboards, a slight majority of the respondents (52%) had considered and rejected different alternative keyboards. However, this trend does not hold between the different alternative keyboards, as is shown in Table 11.

Table 11

Other Alternative Keyboards Considered and Rejected?

Keyboard Selected	Users Considering Other Alt. Keyboards	Users Not Considering Other Alt. Keyboards
Adesso	83%	17%
Comfort	75%	25%
DataHand	100%	0%
ErgoLogic / FlexPro	88%	12%
Kinesis	76%	24%
LexMark Select-Ease	79%	21%
Apple Adjustable	19%	81%
Maltron	50%	50%
Microsoft Natural	34%	66%

User responses indicate an increased tendency to consider other alternative keyboards prior to purchasing the more uniquely-designed and costly products. The Adesso appears to be an exception to this finding and is most frequently compared with the Microsoft Natural (50%) and Apple (30%) keyboards. When the adjustable and sculpted keyboards were tried (30%), Adesso users thought they were too costly.

The Apple Adjustable keyboard users have considered the fewest number of other alternative keyboards. One user responded that there were "not really any other ergonomic choices at the time".

Limited responses on the Maltron came from the United Kingdom where the Microsoft Natural was the only other keyboard considered by respondents.

The Microsoft Natural keyboard had by far the most respondents in this survey and its users have the opposite trend related to considering other alternative keyboard products. Those that did try other keyboards looked at some of the adjustable and sculpted ones (56%) and had concerns with their cost, availability, ease of adjustment, and the ability to get used to the more radical designs. Lower-cost fixed-split keyboards (25%) either did not help the users' problems or they found the Natural to be more comfortable.

The other Sculpted, Adjustable Split, and DataHand keyboard users considered the Fixed Split keyboards only 25% of the time and did not like the lack of adjustability, key feel, overall quality, and they were not as comfortable. The higher-end products were compared 70% of the time. Reasons for not selecting these keyboards include their cost, too radical of a design, increased time to learn how to use, key feel, required too much

finger movement to use, would not maintain adjusted angle setting, and they were not as comfortable or caused pain.

Setup and Use of Alternative Keyboards

Alternative keyboards typically only required a few minutes to set up, with 85% of the users saying it took 10 minutes or less. The only apparent exception was where additional programming was required to allow the keyboard to be used on non PC or Mac computers and also in customizing key layouts. Most users were able to figure out how to set up their keyboards without external help (67%). Some users referred to keyboard instructions (22%) or books and articles (4%). Other users enlisted the aid of medical, ergonomics, or computer specialists (6%) to help them set up their keyboards.

Keyboards are not the only changes that people make as is shown in Table 12. Other workplace modifications were made by 74% of the questionnaire participants. Keyboards were also set up on a variety of surfaces ranging from user laps to adjustable computer tables or trays (see Table 13). Of those using keyboard trays, 68% of them were adjustable.

Table 12

Other Workplace Changes Made

Changes Made	% Responses
New Chair or Chair Adjustment	41%
Adjusted Monitor Height	26%
Different Pointing Device	26%
Keyboard Tray/Drawer	25%
Adjusted Work Surface Height	16%
Foot Rest	13%
New Work Surface	10%
Method Changes / Breaks	7%
Wrist Rest	7%
Voice Dictation/Command System	6%
Document Holder	4%
Telephone Headset	3%
Rest Break Software	2%
Glare Screen	2%
Arm Rests (Forearm Supports)	2%
Dvorak Keyboard Layout	2%
Foot Pedals	1%
Computer Eyeglasses	1%
Slant Board	1%

Table 13

Keyboard Support Surfaces Used by Participants

Keyboard Selected	% Responses
Keyboard Tray	34%
Desk or High Table (28-30")	33%
Computer Table (26-27")	23%
Adjustable Table	6%
In Lap While Seated	3%

Table 14 shows wristrest use by keyboard category and whether the wristrest that came with the keyboard (or is integral to it), a separate wristrest, or other arm support is used. In this case, the DataHand is included in the Adjustable Split category. The "Tenting" keyboards are analyzed separately, but are also included in the Adjustable Split category.

Table 14

Use of Wristrests by Keyboard Categories

Keyboard Category	Wristrest		Wristrest Type		
	Used	Not Used	Keyboard	Separate	Other
Fixed Split	71%	29%	80%	18%	4%
Sculpted	54%	46%	69%	23%	8%
Adjustable Split	52%	48%	58%	27%	15%
Tenting Only	45%	55%	44%	39%	17%

User questionnaire responses indicate that they recognize what adjustments are available on their specific keyboard and even sometimes adjust non-adjustable keyboards by using external objects to slant them as desired. Figures 5 and 6 show the ranges of horizontal opening angles and vertical tenting angles are being used by the survey participants.

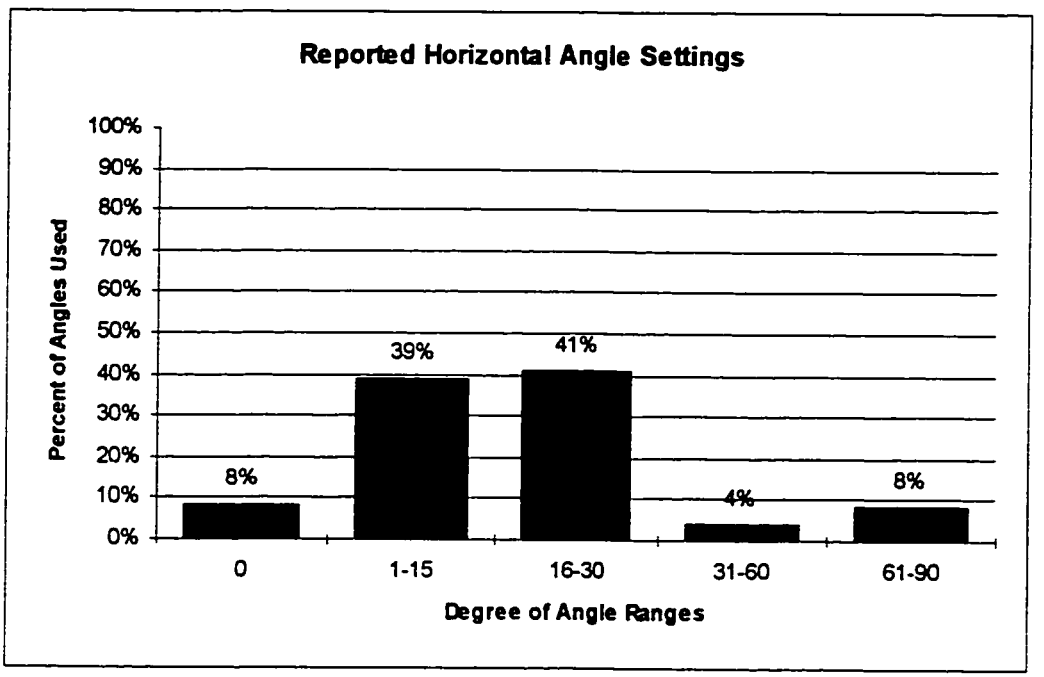


Figure 5. Horizontal split angles used on adjustable keyboards

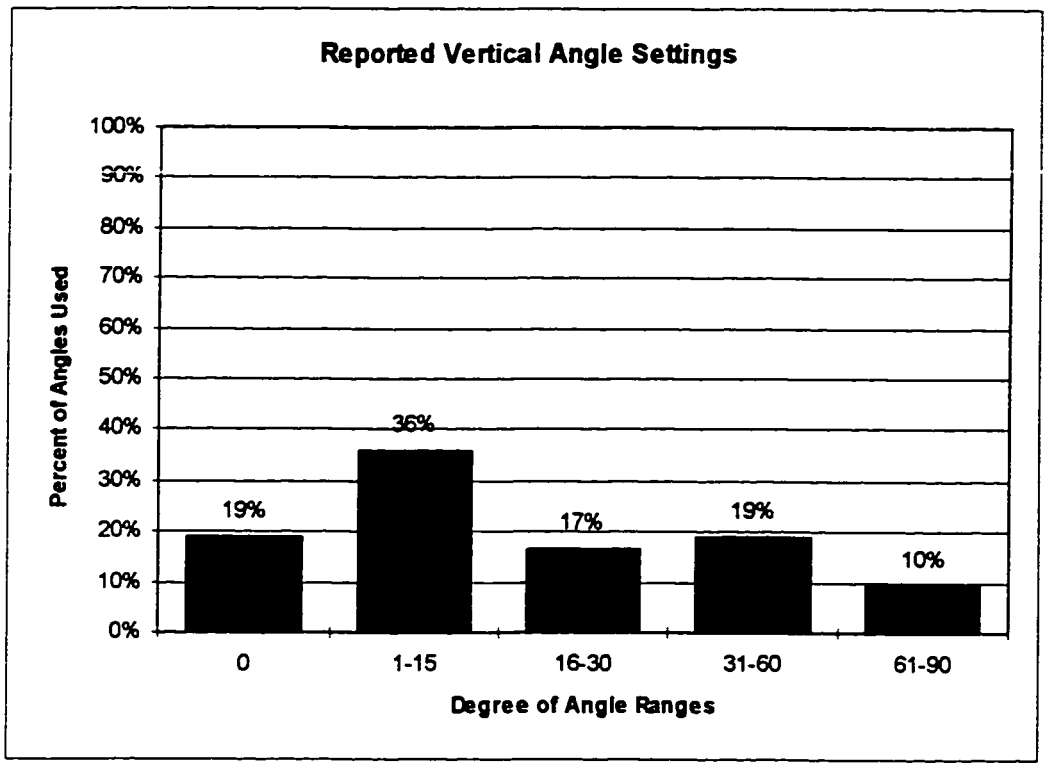


Figure 6. Vertical inclinations used on adjustable keyboards

Several of the alternative keyboards are able to adjust their amount of tilt, or slope, towards the user. Table 15 shows the tilts used by the respondents. The Sculpted Keyboards do not have an adjustment to change the tilt, no information was provided.

Table 15

Keyboard Tilt Angles Being Used by Keyboard Category

Keyboard Category	Keyboard Tilt		
	Positive	Flat	Negative
Fixed Split	33%	29%	38%
Sculpted	*	*	*
Adjustable Split	44%	39%	17%

* No responses from Sculpted keyboard users

Once the Adjustable Split keyboards are configured by the user, Table 16 shows how often the adjustments are changed.

Table 16

Frequency of Keyboard Adjustments

Adjustment Frequency	% Responses
Hourly	7%
Daily	12%
Weekly	28%
Monthly	7%
Never	38%
When Others Use	5%

Benefits Achieved from Alternative Keyboard

Participants are asked to rate their alternative keyboard against their previous keyboard using a seven point scale running from much worse (1) to much better (7). Ratings include issues similar to previous research covering biomechanical, physiological, productivity, and keyboard preference measures. Table 17 provides a summary of user responses and whether they felt their alternative keyboard was worth more than a standard keyboard. Users were asked if they thought their alternative keyboard was worth more than a standard keyboard. Table 18 shows their responses with additional comments following.

Table 17

Mean Ratings of Alternative Keyboard Benefits (1-7 Scale)

	All N-220	Adesso N=12	Apple N=16	Comfort N=8	DataHand N=7
Arm / Hand Posture	6.1	5.9	6.0	6.9	6.6
Aches & Pains	5.7	5.9	6.1	6.1	5.8
Fatigue from Use	5.6	5.5	5.6	5.9	6.0
Comfort of Use	5.8	5.7	6.3	6.0	6.1
Typing Speed	4.3	4.3	4.5	3.9	3.8
Typing Accuracy	4.2	3.9	4.5	3.9	3.4
Key Positioning	5.1	4.8	5.0	4.8	5.0
Feel of Keys	4.9	2.9	4.7	4.6	6.2
Learning to Use	4.4	4.3	5.0	4.6	2.8
Adjustability	5.3	4.5	6.3	7.0	5.8

Table 17 (con't)

Mean Ratings of Alternative Keyboard Benefits (1-7 Scale)

	ErgoLogic N=8	Kinesis N=21	Lexmark N=24	Maltron N=4	Microsoft N=109
Arm / Hand Posture	6.4	6.5	6.4	6.5	5.9
Aches & Pains	6.1	5.6	5.7	5.5	5.6
Fatigue from Use	5.6	5.5	5.5	5.0	5.6
Comfort of Use	5.8	6.1	5.8	6.0	5.8
Typing Speed	4.0	4.1	4.4	3.5	4.4
Typing Accuracy	4.0	4.1	4.3	3.8	4.3
Key Positioning	4.7	5.7	5.0	5.3	5.1
Feel of Keys	6.4	5.6	4.6	5.8	4.8
Learning to Use	4.5	3.7	4.6	4.0	4.5
Adjustability	6.6	4.3	6.5	2.0	4.7

Table 18

Alternative Keyboard Worth More Than a Standard Keyboard?

	Yes	No
All Keyboards	81%	8%
Adesso	67%	33%
Apple	88%	12%
Comfort	100%	0%
DataHand	71%	14%
ErgoLogic	88%	12%
Kinesis	86%	0%
Lexmark	83%	4%
Maltron	100%	0%
Microsoft	78%	7%

In further response to whether alternative keyboards are worth more than standard ones, the following comments were made. The number of times a response appeared (N) is provided along with the comments.

The Adesso keyboard was stated to be worth more than a standard keyboard because:

- Its pointer is in the center (N=2)
- Reduced pain and increased comfort (N=2)
- It helps maintain health, vitality, career and lifestyle (N=2)
- Better design (N=1)

The Apple keyboard was stated to be worth more than a standard keyboard because:

- Reduced pain and increased comfort (N=6)
- Assists in ability to work and a return to normal productivity (N=2)
- Adjustability (N=1)

The Comfort was stated to be worth more than a standard keyboard because:

- Maintains ability to do job in profession and avoiding surgery (N=3)
- Reduced pain and increased comfort (N=2)
- Fully resolved my problem (N=1)
- The difference between life or death, heaven or hell (N=1)

The DataHand was stated to be worth more than a standard keyboard because:

- Of ability to maintain career and ability to work (N=4)

The ErgoLogic was stated to be worth more than a standard keyboard because:

- Maintenance of health and career (N=2)
- Increased comfort; reduced pain and fatigue (N=1)
- I wouldn't operate without it. Period (N=1)
- It fits me. I can work 4x longer (N=1)
- Preventative measure alone (N=1)

The Kinesis was stated to be worth more than a standard keyboard because:

- Reduced pain and increased comfort (N=9)
- More productive (N=3)
- Improved posture (N=2)
- Novel design, programmability (N=1)

The Lexmark was stated to be worth more than a standard keyboard because:

- Reduced pain and increased comfort (N=5)
- Adjustability / improved posture (N=4)
- More productive (N=1)
- I wouldn't consider using a standard keyboard again (N=1)
- this is the best cost vs. feature keyboard tested and used by myself (N=1)

The Maltron was stated to be worth more than a standard keyboard because:

- Reduced pain fatigue and RSI risk; increased comfort (N=3)
- I can't work with standard keyboards, so its invaluable (N=2)
- Help the healing process and prevent further injury (N=1)

The Microsoft was stated to be worth more than a standard keyboard because:

- Reduced pain and fatigue, increased comfort (N=28)
- Improved posture (N=10)
- More productive (N=5)
- Never go back to regular keyboard (N=2)
- Ability to maintain job (N=2)
- Ergonomic design (N=1)

Recommendations for Changes

Questionnaire participants defined the best and worst attributes about their keyboard and how they felt it might be improved.

Keyboard Best Attributes

A summary of user responses about the best characteristics of their alternative keyboards are as follows.

Adesso's best attributes:

- Split design, key angle (N=7)
- Pointer in the center (N=3)
- Tenting (N=3)
- Palmrest (N=2)
- Tilt adjustment (N=2)
- Improved posture (N=1)

Apple's best attributes:

- Split design, adjustability (N=14)
- Improved posture (N=1)
- Wrist pad (N=2)
- Availability (N=1)

- Separate keypad (N=1)

Comfort's best attributes:

- Adjustability (N=6)
- Separate numeric keypad (N=1)
- Reduced pain (N=1)
- Programmable (N=1)
- Improved posture (N=1)

DataHand's best attributes:

- Key feel and placement (N=2)
- Ability to separate hands. (N=2)
- Ability to be able to type (N=1)
- Reduced, minimal finger movement (N=1)
- Ability to tilt "tenting" (N=1)

ErgoLogic's best attributes:

- Adjustability (N=5)
- Key arrangements and programmability (N=2)
- 1-ounce keystroke (soft key feel) (N=1)
- Neutral forearm can be achieved (N=1)
- No training time needed (N=1)
- Function keys grouped of left side (N=1)

Kinesis's best attributes:

- Key layout, handwells (N=11)
- Programmability (N=9)
- Hand separation, improved posture (N=7)
- Footpedals (N=4)
- Light key force (N=3)
- Improved comfort (N=2)
- Thumb keys (N=1)
- Usable on different computers (Mac, PC, Sun) (N=1)
- More productive (N=1)

Lexmark's best attributes:

- Adjustability (angle & separation) (N=20)
- Reduced pain and increased comfort (N=4)
- Detached numeric keypad (N=4)
- Key tactility (N=3)
- Low profile (N=1)
- Improved posture (N=1)
- Programmable backspace on space bar (N=1)

Maltron's best attributes:

- Shaped to hands, separated key wells (N=4)
- Use of the thumb and being able to easily reach all the keys (N=1)

Microsoft Natural's best attributes:

- Split, curved key layout (N=42)
- Improved posture (N=33)
- Reduced pain, increased comfort (N=16)
- Keyboard tilt adjustment (N=13)
- Key feel (not too mushy or clicky) (N=8)
- Built-in wristrest (N=8)
- Mounding up of keys (N=5)
- Reasonable cost (N=3)
- Ease of use/re-learning (N=3)
- Large keys (N=3)
- Easily available (N=2)
- Modern looking (N=2)
- Fixed angle - compromise/can't screw it up (N=2)
- Co-workers hate it (N=1)
- Software included (N=1)

Keyboard Worst Attributes

A summary of user responses about the worst characteristics of their alternative keyboards are as follows.

Adesso's worst attributes:

- Key feel (spongy, stiff, varies) (N=3)
- Pointer too slow, sluggish and inexact (N=2)
- Lack of adjustability (N=2)
- Location of the return key on the right side (N=1)
- The "6" key would be more accessible next to the "7" even though it would as nicely balanced. (N=1)
- Keyboard seems designed for bigger hands than mine (N=1)

Apple's worst attributes:

- Poor quality of construction, mechanism prone to die, breaks about once a year (N=6)
- Separate number pad, combined with function keys take up too much room (N=4)
- Getting used to the layout and adjusting my touch. (N=1)
- Small buttons, not keys for used function keys (N=1)
- No vertical adjustments (N=1)
- Wrist rests come loose (N=1)
- Could be flatter (N=1)

Comfort's worst attributes:

- Ease of adjustability. Tough to adjust, to get it in the correct position and then tighten it down without accidentally moving the position (N=3)
- Key touch (too heavy, key feel could be smoother, more firm) (N=2)
- Cost (N=2)
- Lack of reasonable arm rest (N=1)
- Takes up much more room (N=1)
- Requires adjustable height keyboard tray (N=1)

DataHand's worst attributes:

- Small hand movements, These tiny finger movements require fine motor skills. (N=2)
- DataHand can result in strained fingers - tenseness from trying to hold and position fingers - getting them to move correctly. I suspect this will lessen as I get more familiar with them . . . (N=1)
- I'm not as fast on it as I am on a regular keyboard (N=1)
- Can't adjust the distance between individual finger wells (N=1)
- thumb key design (N=1)

- It looks weird (N=1)

ErgoLogic's worst attributes:

- The key layout is odd, backslash and "6" key (N=1)
- Lacking horizontal angle (N=1)
- Can't easily pop off keycaps and go Dvorak (N=1)
- Dirt gets in (N=1)

Kinesis's worst attributes:

- Not adjustable (N=6)
- Cursor and escape keys awkward to use (N=3)
- Difficult changing different standard keyboard due to changes in key position (N=2)
- Thumb keys (amount of use & positioning) (N=2)
- Key feel (N=2)
- Having to re-learn (N=1)
- Angle of hands not perfect (N=1)
- Too thick, makes it hard to set low enough (N=1)
- No integrated mouse (N=1)
- Cost (N=1)

Lexmark's worst attributes:

- Noisy key clicks (N=5)
- Adjusting is not "stable", it tends to slip (N=2)
- Not adjustable front to back, for negative tilt (N=2)
- It should have a softer touch (N=1)
- Hard to figure out what ought to be adjusted where, it is simple to do (mechanically) it is hard to decide how. I have an appointment to see my hand therapist with it on site (N=1)
- I would prefer the keyboard sections to adjust closer to 90 degrees (tent), but they won't go that far, make do with about 45-50 degrees (N=1)
- Separate numeric keypad is clumsy to use-I couldn't find a good place for it (N=1)
- Getting used to split space bar (N=1)
- No key programming (N=1)

Maltron's worst attributes:

- Space bar & enter (return) are only reachable from one hand (N=1)
- The numbers (both of which I use a lot) are still hard to reach (N=1)
- Periodically switches modes spontaneously so the keyboard layout changes; also periodically goes into Shift Lock mode spontaneously (N=1)
- The numeric keypad (N=1)

Microsoft Natural's worst attributes:

- Not adjustable enough (N=18)
- Key feel (hard touch, stiff, sticky, clunk, jam/stick, too much pressure) (N=15)
- Large keyboard size (curve, Kb Trays, footprint, mouse reach) (N=14)
- Learning Time (adjust to split, B & 6 key placement, slowed speed) (N=7)
- The Windows keys are in bad locations (N=5)
- Attached keypad (never use, reach to use, increased mouse reach) (N=5)
- Palm rest (hard, too low, curved vs straight keyboard trays/wristrests) (N=4)
- Wide key spacing (N=3)
- Space bar too small (N=1)
- Cost (N=1)

Recommendations to Improve Keyboards

A summary of user recommendations to improve weaknesses in current alternative keyboard designs.

Recommendations to improve Adesso:

- Use better keyswitches (smoother, even force between keys, tactile feel (N=5)
- Trackball instead of button (N=2)
- Make it more adjustable (N=1)

Recommendations to improve Apple:

- Improve the overall quality and durability (N=2)
- Better key switches, improve tackle response (N=2)
- Integral arrows and numberpad With this keyboard I have to move a lot more to reach those keys if I want to since the keypad is a separate entity (N=2)
- Better attachment of wrist rests. Ability to adjust vertical angle of each section i.e. a hinge in the middle (N=1)

- Add lateral angle adjustability, two separate halves that could be positioned completely independently of each other, with a sculpted/cupped shape, w/ screwholes so they could be mounted where comfortable (N=1)
- Integrate function keys (N=1)

Recommendations to improve Comfort:

- Make easier to adjust and fine tune adjustments (N=3)
- Lighter key touch (N=2)
- Reduce cost (N=2)
- Remove need for table by mounting on horizontal bars (N=1)
- Eliminate the need for the extra brain box (N=1)
- Make it a bit more contoured (N=1)

Recommendations to improve DataHand:

- move the pinkie finger well closer to the hand (N=1)
- Make it cheaper, about $500 would be a fair price (N=1)
- redesign thumb keys to be more natural (N=1)

Recommendations to improve ErgoLogic:

- Separate the lateral and vertical adjustments into two separate adjustments (N=2)
- Detach numeric keypad and make it separate unit to move mouse closer (N=2)
- Add additional function keys across the top that could be split laterally with the normal keys (N=1)
- Decrease the price (N=1)

Recommendations to improve Kinesis:

- Separate the hand wells, make adjustable (N=7)
- Make a third pod for a numeric keypad (possibly optional) (N=1)
- Function keys are little rubber "chicklet" keys. I would like to see those changed to real keys. (N=1)
- Adjustable key touch (make silent option available) (N=1)
- Make feel of keys better (N=1)
- Allow more than two foot-switches (N=1)
- Minimize thumb use (N=1)
- Find some way to use a mouse without moving my arms so much (integrated pointing device.) (N=1)
- Reposition thumb keypads, since some of the keys are harder to reach (N=1)

- I would do something with the wristrest (not sure what) (N=1)
- I wish the power key was on the keyboard instead of a separate adapter box since I have to hit command-power for Macintosh debugging often (N=1)
- Reposition the cursor keys, move the alt keys a little further out from the center, and find some way to get the shift keys under my thumbs. Also, the function keys are not terribly user friendly where they are (N=1)
- Move the Esc. key to one of the left thumb buttons (N=1)

Recommendations to improve Lexmark:

- Remove click and decrease key actuation force (N=7)
- Footpedals would be good (N=1)
- Some sort of self tuning system; It is unclear how it ought to be configured (N=1)
- Don't provide the tenting feature- can't get forearm support with hands raised. (N=1)
- Increase height adjustability level (N=1)
- Make adjustment easier with better ball joint (N=1)
- Bring the ESC key closer to the main body of the keys (N=1)

Recommendations to improve Maltron:

- Increase spacebar and enter key accessibility to both hands (N=1)
- Make it fold up so I can pack it more easily on business trips! Improve cosmetic appearance (currently black with gray keytops) Move the ESC key further from the digit 1 key (N=1)

Recommendations to improve Microsoft Natural:

- Make more adjustable (N=25)
- Better key design (light action with tactile and audible feedback option) (N=11)
- Built-in pointing device (N=9)
- Detachable numeric keypad (N=4)
- Make wristrest padded, adjustable (N=3)
- Eliminate or provide separate wristrest (N=3)
- Make keyboard smaller (N=2)
- Programmable layout (N=2)
- Move or add a B and 6 to both sides of the keyboard for those who don't use the "correct" hand to press these keys (N=2)
- I Prefer "Y" key on the left instead of the right (N=1)
- Increase the lateral keyboard angle (up to 45 degrees) (N=1)

- Home keys need "center marks". Or more prominent tactical feel markers. (N=1)
- I opened up and loosened up the keys - made for a much better feel (N=1)
- Move Window keys (N=1)
- Thumb-operated "Enter" key (N=1)
- Add a delete key to the left side of the keys (to use when mousing) (N=1)

Chapter 4

DISCUSSION

User Information

The participants in this survey study represent users of a wide variety of alternative keyboard brands and types. Respondents are heavy keyboard users as they indicate an average of 6.3 hours spent on the computer daily, with 68.6% of that being on the keyboard. Most of the users can touch-type, but still need to look at the keyboard occasionally. Others are fully able to touch-type and a single respondent is using the "hunt and peck" method of typing. As the sculpted keys and higher vertical inclinations of these keyboards may reduce key visibility, the ability to touch-type and learning well the selected alternative keyboard is important item to note.

Alternative Keyboard Information

Overall survey results show that alternative keyboards are obtained primarily to alleviate an existing injury or to avoid being injured. There is more of a tendency to acquire one of the more readily available commercial keyboards (Adesso, Apple, Microsoft) for avoiding potential injury as compared to the more medically or injury accommodation-oriented keyboards (DataHand, Comfort, Lexmark, ErgoLogic, Kinesis, and Maltron). The Adjustable Split Keyboards were ranked as having been acquired as much for their adjustability as to the likely goal of addressing an existing injury or pain.

Selection of alternative keyboards appear to be related most strongly to the split or separated key fields that are provided by alternative keyboards. The Adjustable Split

Keyboards again ranked high on adjustability being a primary selection factor on the par with the split key configuration. Cost, key force and an integrated palmrest were also issues of importance to users depending somewhat on which alternative keyboard was selected. Key programmability shows a lower level of influence across the general user group, however, can be important to those who use special control keys in the tasks they perform. This is shown particularly in the responses from the Kinesis users.

Consideration of other alternative keyboard products varied considerably between the commercially- and medically-oriented keyboards. A prime example is the Microsoft Natural keyboard which 2/3 of the time was purchased directly from a store or catalog without considering, or even knowing the existence of, other alternative keyboard options. The Apple Adjustable keyboard also showed this tendency, however, at the time there were very few options of alternative keyboards that were compatible with Apple computers. A similar comment would be valid for the Maltron keyboard being sold in the United Kingdom; there simply are not that many options being provided. Users of the other commercially-oriented keyboard (Adesso) made comparisons frequently, however those were frequently with other the commercially-oriented keyboards (Microsoft and Apple) because the medically-oriented keyboards were considered too costly. The Adjustable Split and Sculpted keyboard users occasionally contemplated the commercial Fixed Spilt keyboards, but disliked the quality, lack of adjustability, and were not as comfortable. When users compared between the medically-oriented Adjustable Split and

Sculpted keyboards they were concerned with cost, availability, ease of adjustment, and the ability to get used to the more unique designs.

Setup and Use of Alternative Keyboards

Setting up the keyboards appear to have no major obstacles unless a converter box is needed to make a PC keyboard work on Mac or Sun workstations. Key programmability also adds time to the setup process.

A variety of other workplace changes are made by alternative keyboard users. Most of these changes focus on improving the seating and an improved arrangement of the computer workstation around the user. More rare and unique additions include voice command/dictation systems and switching the keyboard's key configuration to a Dvorak layout.

Keyboard workstations use various support surfaces. Of concern would be that 33% of alternative keyboard users still use desk or high table surfaces that are likely to be too high for a proper interface with the keyboard. Most of the other users report having either a keyboard tray or table designed for computer use.

Wristrest use varies between the different keyboard types. Fixed Split keyboard users have a higher tendency to use wristrests (71%) which typically is integrated with the keyboard. Sculpted and Adjustable Split keyboards have a lower use of wristrests (54% and 52% respectively). A closer look at the keyboards that vertically tent shows the lowest wristrest use of all (45%), the lowest use of the wristrest coming with the keyboard (44%) and the highest use of "other" supports such as swiveling forearm supports. This is

of particular interest because of Marklin and Simoneau's (1996) recent presentation of preliminary results on upper extremity posture of typists using alternative keyboards. One of the measurements reported, indicated radial deviation at the wrist during use of a vertically inclined alternative keyboard (ErgoLogic). As keyboards are tented upwards, the effective keyboard height raises above the effective use range of any flat wristrest. If users let their unsupported wrists "sag" down, radial deviation occurs. This is noted by one survey participant that stated: "Don't provide the tenting feature - can't get forearm support with hands raised." This identifies a real concern that while trying to solve one postural problem with keyboard design, others may appear. The higher use of forearm support devices by users of tenting alternative keyboards may be an attempt to address this problem. Also, the high use of adjustable keyboard trays may also help accommodate the effective raising of the keyboard's home row when the key segments are vertically inclined.

Adjustable Split keyboard configurations reported by users usually fell within the range suggested by past laboratory research. Horizontal split angles were set to low to moderate angles (1-30°) by 80% of the users. Some users (8%) left their keyboards straight while 12% reported angles in the 31-90° range, which may be excessive and result in radial wrist deviation during use. Vertical angle settings represent a much wider range of settings across 1-60° for 72% of the users while 10% use the 61-90° range. Some users (19%) left their keyboards flat. User responses on keyboard tilt was fairly evenly distributed between the positive, flat, and negative tilt orientations. It is worthy of note that 1/3 of Adjustable

Split keyboard users do not adjust their keyboards once set. The remainder of the users periodically readjust their keyboards for variety, comfort, or when someone else uses their keyboard and changes the setting.

This draws an interesting parallel to another costly computer workplace accommodation, the ergonomic chair. Is it best to set it up and leave it in its "proper" setting or should the adjustments be moved frequently to provide variety and comfort? This raises the question of whether the product should be produced in a fixed configuration, that is designed to accommodate most of the users, thus avoiding the possibility of the product being mal-adjusted in such a way that is harmful for use. On the other hand, fixed orientations rarely fit the variety of shapes and sizes that people come in, thus adjustability is needed. Both alternative keyboards and chairs deal with this dilemma and have products designed that fit these basic philosophies.

Benefits Achieved from Alternative Keyboard

Reported benefits of alternative keyboard use follow closely with earlier laboratory research. All alternative keyboards rated highly in the posture and comfort areas as compared to the standard keyboard. Ratings on adjustability were high for the Split Adjustable keyboards and lower for the others. Productivity issues such as typing speed and accuracy, along with learning to use, generally did not show any major difference as compared to the standard keyboard. A couple of exceptions, however, would be the DataHand and Kinesis keyboards with more unique design solutions which results in increased learning curves and occasional problems when switching between alternative and

standard keyboards. These ratings correspond well with earlier studies where initial productivity slows down and then increases towards original levels over time (Honan, et al., 1995; Smith & Cronin, 1993; Brigham & Clark, 1986). Key feel is an important issue for many users, which is indicated by many of their comments and recommendations. The ErgoLogic, DataHand, and Kinesis keyboards rated the highest for improved key feel characteristics, while the other keyboards more closely match the key feel of the standard keyboard.

Overall, 81% of the users felt that their alternative keyboard was worth more than a standard keyboard. Reasons given for this ranged from it is worth my health, vitality, career, and lifestyle to improved posture, comfort, and reduced pain. Some even noted that split keyboards are plainly better and that they would never return to a standard keyboard again.

Recommendations for Changes

The users consider the best attributes of alternative keyboards to be the split or separated designs, improved posture, reduced pain and increased comfort, key feel, adjustability, key programmability, and a separate numeric keypad.

Comments on the worst attributes include: a spongy or stiff key feel, poor quality, lack of adjustability or hard to adjust, changes in the key layout due to the split or sculpted key designs, and learning time for the more unique keyboards.

Recommendations for improvement cover increasing keyboard adjustability, better key design with a light action and tactile feedback, inclusion of an integrated pointing device

(typically a touchpad or trackball), a detachable numeric keypad for positioning flexibility and allowing the mouse to move closer, varied suggestions of relocating specific keys, and reducing alternative keyboard costs.

Limitations of the Study

The majority of the questionnaire responses were through the Internet or company "in-house" electronic mail distribution. Because of this, there may be an under-representation of alternative keyboard users that are not on the net and are difficult to identify and contact without direct access to the records of keyboard manufacturers and medical professionals.

A large portion of the survey participants use Fixed Split keyboards (58%), with Sculpted keyboards (11%) and Adjustable Split keyboards (30%) having a lower response rate. This may skew the information that is provided across all alternative keyboards more towards products such as the Microsoft Natural. Keyboard and category specific information reported in this paper will provide a better representation for individual products and types of designs.

The questionnaire may have resulted in learning effects in the participants. This is of particular importance in the case of Microsoft Natural users where 66% had not considered other alternative keyboards. Some users also mentioned in their surveys that they had not been aware of the existence of other alternative keyboard products. A potential effect of this is where users' expectations have been changed and they now expect increased adjustability and other features previously unknown to them.

As most of these keyboards are quite costly, it would be typical human nature to justify that purchase to themselves, as well as in a questionnaire. This "cognitive dissonance" would possibly result in the need to enhance the good points of the selected product and diminish the characteristics of the products not selected. As the purchase of an alternative keyboard to reduce injury symptoms may have more "real" effects on the user as compared to the purchase of a car, then this effect may not be that great. Participants appeared to be fairly liberal with their praise and scorn of the products they tried, rejected, and are currently using.

Future Research

Areas for future research include direct observation of alternative keyboard users. The question becomes is what users say what they are really doing? Much of the information collected in the survey on keyboard angles was designed so that no measurement instruments would be required. As such, the angle ranges should have been fairly clear to participants. However, this can not be taken for granted and actual observation and measurement of not only the keyboard configuration, but user's operating postures while using these products in the "real world" would add significantly to the results of this study.

There are some concerns about increased injury risk factors related to vertically inclined keyboards. Additional research into any special accessories or furniture that might assist in providing adequate support and guidance to users of vertically inclined keyboards may address the radial deviation noted by Marklin (1996).

In follow-up discussions with subjects in Morelli, et al.'s (1995) study on user preferences between different alternative keyboards, they noted a positive acceptance for detachable numeric keypads. The present study also recorded several comments about keyboard length and additional flexibility if the keypads were detachable. According to overall survey responses, the numeric keypad is used an average of only 4% of total computer time. The subjects in Morelli, et al.'s study predominantly used the numeric keypad and found benefit in having it detached. Additional study into the impacts of removing the redundant keys of the numeric keypad from the keyboard to allow closer pointing device placement and/or making a detached version that can be placed to the right or left of the keyboard merits further investigation.

The present study has predominantly focused on the current alternative keyboard user who has typically already been injured or considers himself/herself at risk of injury before acquiring an alternative keyboard. Cakir (1995) studied the acceptance of the adjustable keyboard and makes some comparisons to an earlier study of acceptance of a fixed-angle split keyboard. This may be a start in making the leap between the Fixed Split keyboard designs and the Adjustable Split designs. As the prices decrease and make these products more affordable for proactive purchases, strategies in implementing alternative designs into the workplace needs additional research and consideration.

Chapter 5

CONCLUSIONS

This study provides insight into the primary factors involved in the selection process between the commercially available alternative keyboard designs. To some extent there appear to be two markets for alternative keyboards. One is the mass-marketed Fixed Split keyboards that users are finding and using for injury prevention and accommodation with rarely any insight into other available products. The second market is medically-related for the more costly Sculpted and Adjustable Angle keyboards. These keyboards are advertised in medical product catalogs and specialty shows focused on medical and ergonomics professionals. As such, these products to date have largely been hidden from potential users until after an injury has occurred.

The majority of adjustable keyboard users seem to prefer moderate adjustment angles while typing, which is consistent with previous research. Positive responses were obtained related to keying posture and comfort while using the alternative keyboards with no corresponding loss in keying accuracy and speed. Some learning curve issues exist for the more unique designs, such as the DataHand and Kinesis keyboards.

Over 80% of the users felt that their alternative keyboards are worth more than the standard keyboard previously used. Several users feel uncomfortable returning to standard keyboards and others state that they would not have been able to continue in their jobs, or would have undergone surgery, had it not been for the alternative keyboard being used. Users report improved posture and comfort, and reduced pain, from the split, sculpted and

adjustable keyboard configurations investigated in this survey study. Of concern to users was the poor quality of some products, especially of the feel and action of the keyboard keys. Some personal preferences appear related to key feel as some prefer the "clicky" keys while others dislike the noise and prefer a quiet, smooth action. Much like the earlier-mentioned similarity to ergonomic chairs, many users are trying out the alternative keyboards and comparing cost to features and comfort. Each alternative keyboard has its benefits and drawbacks; however, users do appear to benefit from their use and in some cases could not work without them.

Survey responses from alternative keyboard users in business, government and educational settings have provided insight into the primary factors involved in the selection process, setup, use characteristics and perceived benefits between the commercially available alternative keyboard designs. Results from this study not only show that keyboard configurations and benefits as described in laboratory research have "real world" validity and benefit, but also provide information needed to focus user education, research and design efforts in the field. It must be emphasized, however, that keyboards are only part of the CTD epidemic and thus other aspects of the workplace (both products and practices) also need to be surveyed and observed as well, so we can better understand and address these problems in the office environment and elsewhere.

REFERENCES

Andre, D.A., and Segal, L.D. (1993, October). Design functions. Ergonomics in Design, 4-6.

Bailey, R.W. (1982). Human Performance Engineering: A guide for system designers. Englewood Cliffs, NJ: Prentice-Hall.

Brigham, F.R. and Clark, N. (1986). Comparison of initial learning and acceptance: STR ergonomic keyboard vs. standard keyboard (653-ITT-00894). Essex, England: ITT Europe.

Cakir, A. (1995). Acceptance of the adjustable keyboard. Ergonomics, 38(9), 1728-1744.

Cooper, W.E. (1983). Cognitive aspects of skilled typewriting. New York, NY: Springer-Verlag.

Creamer, L.R., & Trumbo, D.A. (1960). Multifinger tapping performance as a function of the direction of tapping movements. Journal of Applied Psychology, 44, 376-380.

Cushman, W.H. & Rosenberg, D.J., (1991). Advances in Human Factors/Ergonomics 14: Human Factors in Product Design. New York: Elsevier. pp. 179-193.

Duncan, J., & Ferguson, D. (1974). Keyboard operating posture and symptoms in operating. Ergonomics, 17, 651-652.

Feder, B.J. (1992, June 8). New liability threat to computer manufacturers. San Francisco Chronicle, pp. C1, C10.

Ferguson, D., & Duncan, J. (1974). Keyboard design and operating posture. Ergonomics, 17, 731-744.

Gerard M.J., Jones, S.K., Smith, L.A., Thomas, R.E., & Wang, T. (1994). An ergonomic evaluation of the kinesis ergonomic computer keyboard. Ergonomics, 37, 1661-1668.

Hobday, S.W. (1988). A keyboard to increase productivity and reduce postural stress. In F. Aghazadeh (Ed.), Trends in Ergonomics/Human Factors V (pp. 321-330). New York: North-Holland.

Honan, M., Serina, E., Tal, R., & Rempel, D. (1995). Wrist postures while typing on a standard and split keyboard. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting (pp. 366-368). Santa Monica, CA: Human Factors Society.

Ilg, R.(1987). Ergonomic keyboard design. Behavior and Information Technology, 6, 303-309.

Jewell, M. (1995, November 6). Ergonomic keyboards find niche. San Francisco Chronicle.

Klockenberg, E.A. (1926). Rationalisierung der Schreibmaschine und ihrer Bedienung (Rationalization of typewriters and their operation). Berlin: Springer.

Kroemer, K.H.E. (1972). Human engineering the keyboard. Human Factors, 14, 51-63.

Lopez, M.S. (1993). An ergonomic evaluation of the design and performance of four keyboard models and their relevance to carpal tunnel syndrome, Unpublished doctoral dissertation, Texas A&M University, College Station, TX.

Lueder, R.K. (1985) How to use computers without using keyboards. Office Ergonomics Review, 2(1), 22-24.

Lyon, B.K. (1992, June). Video display terminal ergonomics. Professional Safety, 32-39.

Marklin, R.W., & Simoneau, G.G. (1996). Upper extremity posture of typists using alternative keyboards. Proceedings of the Silicon Valley Ergonomics Conference & Expositon. (pp. 126-132). San Jose, CA: Silicon Valley Ergonomics Institute.

Morelli, D.L., Johnson, P.W., Reddell, C.R., & Lau, P. (1995). User preferences between keyboards while performing "real" work. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting (pp. 361-365). Santa Monica, CA: Human Factors Society.

Nakaseko, M., Grandjean, E., Hunting, W., & Gierer, R. (1985). Studies on ergonomically designed alphanumeric keybords. Human Factors, 27, 175-187.

Noyes, J. (1983) The QWERTY keyboard: A review. International Journal of Man-Machine Studies, 18, 265-281.

Pan, C.S., Swanson, N.G., Galinsky, T.L., & Steward, L.L. (1994). Role of the keyboard design in performance, musculoskeletal discomfort and fatigue. Proceedings of the Human Factors Society. Santa Monica, CA: Human Factors and Ergonomics Society.

Pulat, B.M., (1992). Fundamentals of Industrial Ergonomics (pp. 259-262). Englewood Cliffs, N.J.: Prentice Hall.

Smith, W.J., & Cronin, D.T. (1993). Ergonomic test of the kinesis keyboard. Proceedings of the Human Factors Society (pp. 318-322). Santa Monica, CA: Human Factors and Ergonomics Society.

Smutz, P., Serina, E., & Rempel, D. (1994). A system for evaluating the effect of keyboard design on force, posture, comfort and productivity. Ergonomics, 37, 1649-1660.

Sommerich, C.M (1994). Carpal tunnel pressure during typing: effects of wrist posture and typing speed. Proceedings of the Human Factors Society 1. Santa Monica, CA: Human Factors and Ergonomics Society.

Thompson, D.A., Thomas, J., Cone, J., Daponte, A., & Markison, R. (1990). Analysis of the TONY!™ variable geometry VDT keyboard. Proceedings of the Human Factors and Ergonomics Society 34th Annual Meeting (pp. 365-369). Santa Monica, CA: Human Factors Society.

Wallach, D. S. (1995). Typing Injury FAQ: Keyboard Alternatives [On-line] Available: via anonymous ftp from rtfm.mit.edu in pub/usenet/news.answers/typing-injury-faq/keyboards/.

Weiss, N.D., Bloom, T., Gordon, L., & Rempel D. (1992). Wrist Position Of Lowest Carpal Tunnel Pressure: A New Method To Measure Intracarpal Pressure As A Function Of Wrist Position. Phoenix, AR: American Society for Surgery of the Hand.

Zip, P., Haider, E., Halpern, N., & Rohmert, W. (1983). Keyboard design through physiological strain measurements. Applied Ergonomics, 14, 117-122.

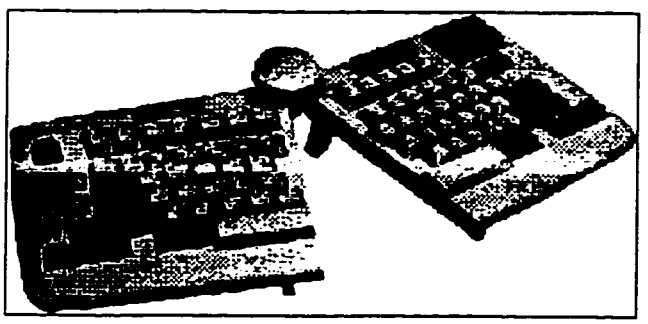
APPENDIX A

Alternative Keyboard Manufacturer Information

Health System's Comfort Keyboard System

The Comfort™ Keyboard System consists of three sections (left-hand, right-hand and numeric keypad) that are independently adjustable and rotates and tilts to any position. This maximum adjustability increases user comfort and reduces fatigue. The numeric keypad can be positioned on the left yielding greater comfort and accessibility for left-handers. The sections can be moved apart, to conform to each user's shoulder width, for greater comfort. The Comfort™ Keyboard System uses the familiar QWERTY key arrangement with state-of-the-art light touch keyswitches providing tactile feedback. It also has a variety of programmable functions (macros, etc.) to increase productivity.

Lexmark's Select-Ease Keyboard

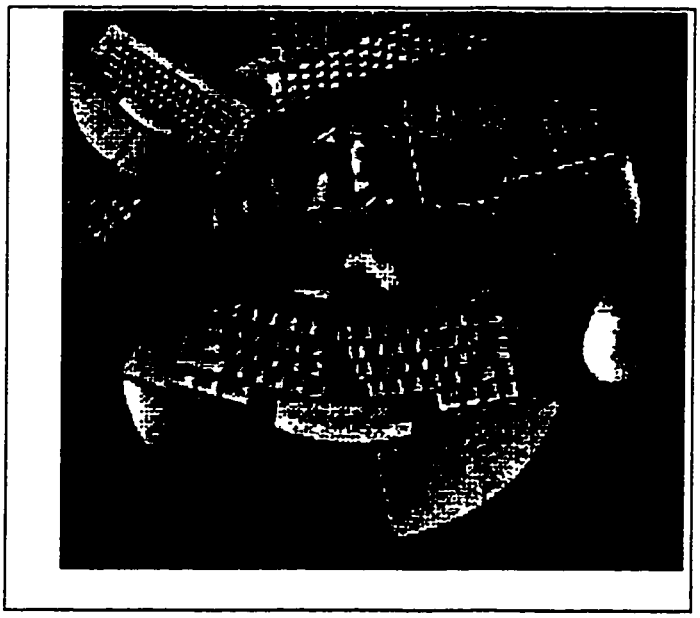


The new Select-Ease from Lexmark features an innovative design for flexibility and adjustability. It can be shaped into any number of different positions for individual comfort. A

knob located in the middle permits the user to easily set the preferred position when the keyboard halves are attached together. The Select-Ease also splits into separate halves with adjustable legs that provide support in various positions.

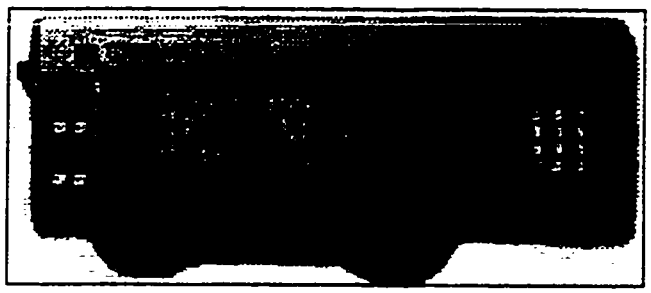
Other features include a low-stepped profile and the Erase-Eaze feature that allows the user to re-program either of the two spacebars to be a backspace key. This allows typists to backspace and correct errors without ever lifting the hands from the home row position. An inverted-T cursor key arrangement is also provided on each keyboard half to accommodate both left- and right-handed typists. A new 17-key detached numeric pad has a 21-inch cable which allows it to be placed on either the left or right side and has legs to adjust its slope and tilt.

Apple's Adjustable Keyboard



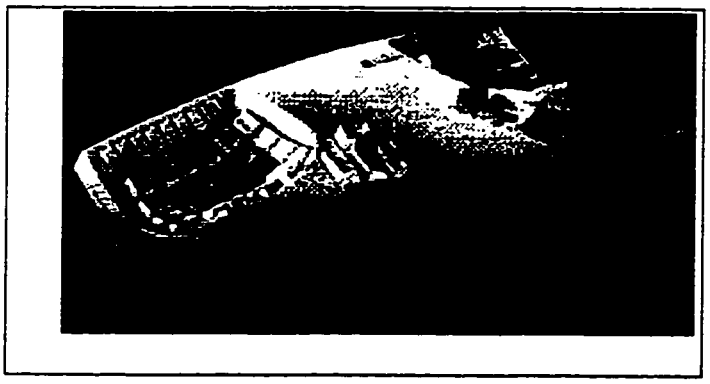
The Apple Adjustable Keyboard is a semi-split keyboard that allows users to separate the two sides up to 30 degrees. It comes with a palm rest which helps maintain the wrist and hand in a neutral posture. The keyboard, however, is flat and does not have lateral angle adjustability. A separate numeric keypad comes with the keyboard.

ErgoLogic and Keytronic's FlexPro Keyboards



The ErgoLogic and Keytronic's FlexPro keyboards are adjustable split keyboards for user comfort. The opening and lateral angles are linked into a single knob control and are not independently adjustable. Built-in handrests slide under user's palms to provide needed support. Split space bars are programmable so that pressing them from the ends performs backspace and enter functions. The QWERTY key layout is used to avoid relearning and achieve the same speed and efficiency as an ordinary keyboard.

Kinesis Keyboard

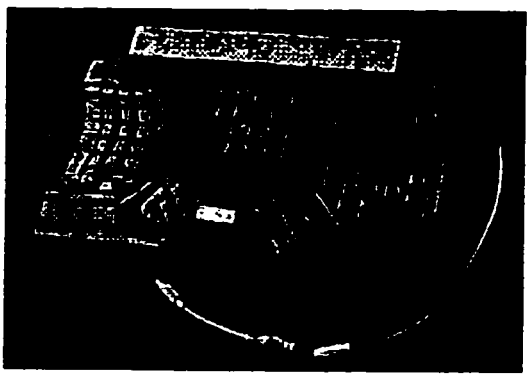


The Kinesis keyboard's keys are set in two concave "dishes" on either side of the keyboard. Columnar key arrangement eliminates awkward, diagonal reaches. Easy-to-reach function keys limit awkward motions. Onboard programmability allows simple, rapid customization of key layout and macro creation. Foot switches can perform keystrokes, redistributing workload away from fingers. Thumb keys re-allocate workload and reduce stressful sideways movements.

Tactile, long-stoke, mechanical switches require minimal force and travel to activate. Familiar QWERTY layout minimizes adaptation time. Fixed ergonomic design fits a broad range of hand sizes while safeguarding against misadjustment.

Kinesis' design has been validated by extensive, ongoing research, global ergonomic technologies performed by independent laboratories in accordance with procedures established by the International Standards Organization (ISO). The study concludes that Kinesis keyboards demonstrate "substantial physiological advantages, good performance, and more user preferences" when compared to traditional keyboards. Participants preferred Kinesis keyboards for comfort, usability and reduced fatigue. Other research shows that the transition to the Kinesis keyboard is simple, with most users regaining their previous productivity within the first few days.

Applied Learning's Maltron Keyboard

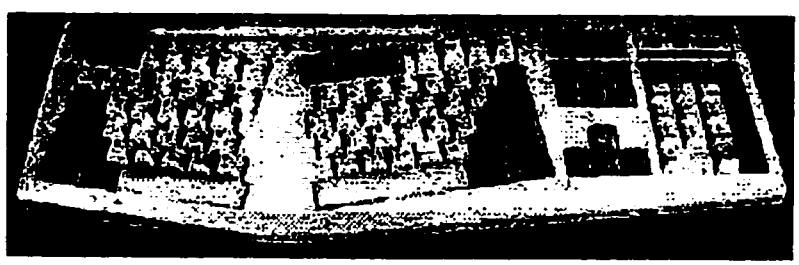


Applied Learning's Maltron keyboard has split and separated letter keys into two sections with the numeric pad in the center. It has a QWERTY configuration with alternative layouts available.

DataHand

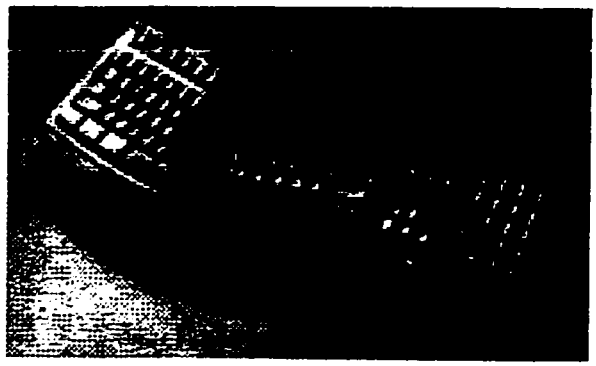
DataHand® users place each hand in a separate unit with five computer keys surrounding each fingertip and thumb. This arrangement minimizes finger movement, and reduces stress and strain. Unlike flat keyboards, even the function keys are touch-typeable.

Generic Split Keyboard



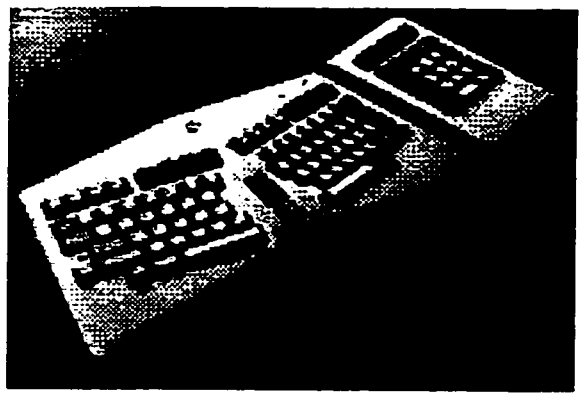
This is a general name for a variety of keyboards on the market with names such as Clevo KB7000 by Norton Technologies. What these keyboards have in common is that they modify the standard keyboard using a V-shaped design. The alphanumeric key areas are split into left and right hand keypads, however, the keyboard remains flat with no lateral inclination. A standard QWERTY key arrangement is maintained so users can easily adjust to its design without adversely affecting productivity. It has a high quality mechanical key switch design that provides smooth key operation.

Microsoft's Natural Keyboard



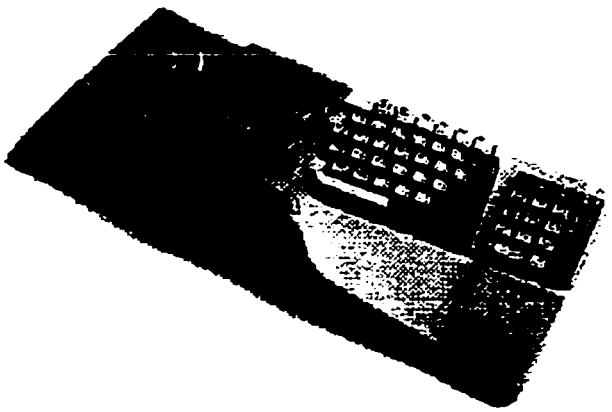
The new Microsoft Natural Keyboard is responsibly designed for maximum comfort. Its split-key, sloped keyboard promotes a natural wrist posture. A built-in palm rest provides a comfortable resting place for hands while not typing. The keys have a soft, tactile action and standard QWERTY key layout for adapting to the split keyboard quickly.

Marquardt Switches' MiniErgo Keyboard



Marquardt Switches' MiniErgo keyboard has fixed split and lateral angles to reduce hand deviation and wrist bending. The gently sloping V configuration allows a typist's hands to be in a comfortable, neutral position. It comes with a QWERTY layout and an embedded numeric keypad. An optional, separate numeric keypad can be positioned to the right or left of the keyboard. Technical University in Darmstadt, Germany, has shown that typing performance at least equal to conventional keyboards can be in a short time, but with less effort.

MIKey



The MIKey keyboard angles and splits. Function keys are arranged in a circular position to reduce user's having to look between the screen, keyboard, and copy material.

APPENDIX B

Alternative Keyboard Survey

ALTERNATIVE KEYBOARD SURVEY

Can you help with a user survey of alternative keyboards? (e.g. Microsoft Natural, Kinesis, Lexmark, Comfort, DataHand, etc.) If you don't use an alternative keyboard, please pass this on if you know someone else who uses one.

INTRODUCTION

This questionnaire is part of a study being performed for a Masters Thesis in Human Factors and Ergonomics at San Jose State University and is being supported by Interface Analysis Associates. This survey builds upon laboratory research findings and queries actual users about alternative keyboard acquisition, setup, use, benefits, satisfaction, and recommendations for improvement. Insight gained from this study will help improve instructional, research and design efforts in the field.

If you would like a summary of findings or would be willing to participate in follow-up interviews or surveys related to alternative keyboard use, complete the information at the end of this survey.

All survey responses are anonymous, names will not be linked to answers in any way.

- On the Web, <http://www.interface-analysis.com/keyboard/survey.html> will provide a quick and easy means of completing this survey.

- E-mail versions are also available. Contact <wrightks@telis.org> or <andre@interface-analysis.com> for a copy.

  Addressed, stamped envelopes are available or return postage will be refunded as requested. See information on returning the survey at the end of this questionnaire.

Thank You

Kenneth Scott Wright
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INSTRUCTIONS

Please answer all questions as accurately as possible. Check, circle, or write in the response most appropriate for your experiences with alternative keyboards. If you don't want to answer a particular question, just leave it blank. If a particular question is not applicable, or you don't feel comfortable answering a particular question, just leave it blank.

It should take approximately 10 - 15 minutes to complete this survey.

SECTION I: USER INFORMATION

(1) State or Country Residing: _____

(2) Occupation: _____

(3) Age: _____

(4) Height: _____

(5) Weight: _____

(6) Gender: ☐ male ☐ female

(7) Hand Size: ☐ small ☐ medium ☐ large

(8) How do you type? *(check only one)*

☐ hunt & peck ☐ touch type + look at keyboard ☐ touch type

(9) How much computer use do you currently perform each day? _____ hours

(10) Percent of: Keyboard use ____% Numeric Keypad use ____ % Mouse/Trackball use ____ %

SECTION II: ALTERNATIVE KEYBOARD INFORMATION

(11) Which alternative keyboard do you currently use?

☐ Comfort
☐ Lexmark Select-Ease
☐ Apple
☐ ErgoLogic/FlexPro
☐ Kinesis
☐ Maltron
☐ Other: _____
☐ DataHand
☐ Generic Split
☐ Microsoft Natural
☐ MiniErgo
☐ MIKey
☐ Adesso

(12) How long have you been using this alternative keyboard? _____

(13) How much did you pay for this keyboard?_____

(14) Why was an alternative keyboard obtained? *(check all that apply)*

☐ Disability accommodation
☐ Existing injury/pain
☐ Avoid potential injury
☐ Recommended/provided
☐ Adjustable Design
☐ State-of-the-art / looked cool
☐ No particular reason, I didn't know it was "alternative" when I bought it
☐ Other: _____

(15) Who decided on the specific keyboard acquired? *(check only one)*

- ☐ Worker's Compensation / Insurance
- ☐ Medical recommendation
- ☐ Company provided
- ☐ Your Selection
- ☐ Other: _____

(16) Were other keyboards considered and rejected? ☐ yes ☐ no

If yes, which one(s)?_____

Why was each rejected?_____

_____

(17) How was the chosen keyboard selected? *(check all that apply)*

- ☐ Cost
- ☐ Adjustability
- ☐ Split/separated keys (key layout)
- ☐ Key force/feel
- ☐ Key programmability
- ☐ Palm resting surface
- ☐ Recommended by _____
- ☐ Other: _____

(18) How did you hear about the chosen keyboard? _____

(19) Do you have any discomfort when using your current alternative keyboard: *(check only one)*

☐ none ☐ some discomfort ☐ occasional pain ☐ injury ☐ disability

If you chose any option other than "none," please explain:_____

_____

(20) Did you use a different keyboard prior to your current alternative keyboard? ☐ yes ☐ no

If yes, which type and brand did you use?_____

(21) Did you have any discomfort when using your previous keyboard? *(check only one)*

☐ none ☐ some discomfort ☐ occasional pain ☐ injury ☐ disability

If you chose any option other than "none," please explain:_____

_____

(22) Did you make other "alternative" workstation changes? ☐ yes ☐ no

If yes, please list:_____

SECTION III: SETUP AND USE OF ALTERNATIVE KEYBOARD

(23) How long did it take to set up your alternative keyboard?

- ☐ <5 Minutes
- ☐ 5-10 Minutes
- ☐ 10-20 Minutes
- ☐ >20 Minutes
- ☐ Other: _____

(24) Who or what helped the most in setting up the keyboard? *(check only one)*

- ☐ Keyboard instructions
- ☐ Medical practitioner
- ☐ Ergonomics specialist
- ☐ Books or articles
- ☐ Family or friends
- ☐ I figured it out myself
- ☐ Other: _____

(25) Keyboard adjustments available on your keyboard *(check all that apply)*

- ☐ Adjustable opening angle
  [*Opening angle:* A flat, horizontal split (rotated separation) of the left and right hand key fields, where they no longer form straight rows, but consist of two sets of rows with an angular gap in the keyboard's center]
- ☐ Adjustable lateral angle
  [*Lateral angle:* An upwards, vertical raising of the keyboard in its center, like an A-frame or tent, where the hands no longer rest flat, but rotate back towards a handshake position. Also known as tenting]
- ☐ Adjustable keyboard tilt
  [*Tilt:* The keyboard's slope angle going from front to back]
- ☐ Adjustable separation distance between each hand's key sections
  [*Separation:* the physical detachment of the left and right keyboard sections, with or without rotation]
- ☐ Others: _____
- ☐ Don't know
- ☐ None

For those with adjustable keyboards, at what angle did you set the following keyboard features?

(26) Opening angle [horizontal split] *(in degrees)*:

☐ (0) / ☐ (1-15) / ☐ (16-30) / ☐ (31-60) / ☐ (61-90) / ☐ Don't know / ☐ Doesn't apply

(27) Lateral angle [vertical tenting] *(degrees raised from horizontal)*:

☐ (0) / ☐ (1-15) / ☐ (16-30) / ☐ (31-60) / ☐ (61-90) / ☐ Don't know / ☐ Doesn't apply

(28) Adjustable keyboard tilt:

- ☐ Positive tilt - front of keyboard is lower than back of keyboard
- ☐ No tilt (flat) - front and back of keyboard are at same height
- ☐ Negative tilt - front of keyboard is higher than back of keyboard

(29) Separation distance: _____ *(distance between the G and H keys, in inches)*

(30) Other adjustments: _____

(31) Rate your keyboard's ease-of-adjustment on the scale below: *(Skip if not adjustable)*

very easy (1 - 2 - 3 - 4 - 5 - 6 - 7) very hard

(32) How often are changes to keyboard adjustments made? *(Skip if not adjustable)*

- ☐ Hourly
- ☐ Daily
- ☐ Weekly
- ☐ Never
- ☐ Other: _____

(33) Which keyboard adjustments are made, what is typically changed and why? *(Skip if not adjustable)*

_____

_____

(34) Do you use a wrist rest with your keyboard? ☐ yes ☐ no

If yes, do you use:

- ☐ Wrist rest that came with keyboard
- ☐ Separate wrist rest
- ☐ Other wrist or forearm support used. Describe: _____

(35) What surface is the keyboard located on during use?

- ☐ Desk or high table (typically 28-30 inches high)
- ☐ Computer table (typically 26-27 inches high)
- ☐ Adjustable height table (Height(s): _____)
- ☐ Under-table keyboard tray (Adjustable? yes / no)
- ☐ In lap while seated
- ☐ Other: _____

SECTION IV: BENEFITS ACHIEVED FROM ALTERNATIVE KEYBOARD

Rate your current keyboard as compared to your previous keyboard on the scales below:

(36) **Arm/Hand Posture** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(37) **Aches & Pains** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(38) **Fatigue from Use** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(39) **Comfort of Use** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(40) **Typing Speed** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(41) **Typing Accuracy** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(42) **Key Positioning** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(43) **Feel of Keys** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(44) **Learning to Use** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(45) **Adjustability** much worse (1 - 2 - 3 - 4 - 5 - 6 - 7) much better

(46) Is your alternative keyboard worth more than a standard one? ☐ yes ☐ no

If yes, how much more and why?_____

SECTION V: RECOMMENDATIONS FOR CHANGES

(47) What is/are the best attribute(s) of your keyboard?

_____

_____

(48) What is/are the worst attribute(s) of your keyboard?

_____

_____

(49) How would you improve your keyboard if you could?

_____

_____

SURVEY FEEDBACK

If you would be willing to participate in follow-up interviews or surveys related to alternative keyboard use or would like a summary of findings, please fill in the information below. This information will not be included in the final survey results and your identity will be kept anonymous.

☐ Please send me a summary of the alternative keyboard survey's findings
☐ Yes, I would be willing to participate in follow-up interviews or surveys

Name: _____

Address:_____

Phone: _____

E-Mail: _____

RETURNING THE SURVEY

Once this questionnaire is completed, please return it to:

On-line version: <wrightks@telis.org> or
<andre@interface-analysis.com>

Paper version: FAX to (408) 342-9059 or
Mail to Scott Wright, 2013 Princeton Ct., Los Banos CA 93635

Feel free to call if you have questions about the survey:
Home (209) 826-8443, Work (408) 742-3473

Thank you very much for participating in this survey and providing valuable information and feedback related to your experiences in using alternative keyboards.

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